

MISSION REQUIREMENTS FOR A MANNED EARTH OBSERVATORY

TASK 3 - CONCEPTUAL DESIGN

Contract No. NAS8-28013

31 May 1973

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Prepared for

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Marshall Space Flight Center, Alabama 35812

Prepared by

TRW SYSTEMS GROUP/EARTHSAT



ONE SPACE PARK • REDONDO BEACH, CALIFORNIA 90278

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FOREWORD

The documentation on the "Mission Requirements for a Manned Earth Observatory" study, performed for the NASA Marshall Space Flight Center, Huntsville, Alabama, under Contract NAS8-28013 resulted in a four volume report. These volumes are:

Volume I	<u>Task 1 - Experiment Selection, Definition and Documentation.</u> Report No. 21324-6001-RU-00, 31 May 1973.
Volume II	<u>Task 2 - Reference Mission Definition and Analysis.</u> Report No. 21324-6002-RU-00, 31 May 1973.
Volume III	<u>Task 3 - Conceptual Design.</u> Report No. 21324-6003-RU-00, 31 May 1973.
Volume IV	<u>Task 4 - Programmatics.</u> Report No. 21324-6004-RU-00, 31 May 1973.

On this study, TRW Systems was contractually assisted by Earth Satellite Corporation, Washington, D. C., and by Model Development Laboratory, Alhambra, California.

The contents of these reports pertain to the mission requirements and conceptual design of Shuttle sortie payloads that could be flown in the 1980s. In developing this information, projections of 1980 sensor technology and user data requirements were used to formulate "typical" basic criteria pertaining to experiments, sensor complements, and reference missions. These "typical" criteria were then analyzed in depth to develop conceptual payloads that are within the capabilities of the Shuttle/Sortie Lab mission capabilities. These payloads, therefore, should not be considered to be potential candidates for Shuttle missions, but only as typical conceptual payloads.

Future studies will be directed more specifically to the development of requirement and conceptual designs for potential Shuttle payloads, such as a Manned Earth Observatory that would be used as a sensor development Laboratory and to accommodate unique data acquisition requirements that would be supportive and complementary to the earth observations automated satellite programs.

Additional information pertaining to this document may be obtained from the NASA Contracting Officer's Representative, Mr. Donald K. Weidner, Marshall Space Flight Center, Huntsville, Alabama 35812.

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1.0 INTRODUCTION

The primary task requirements during Task 3 of the Manned Earth Observatory Study were:

- Review available Shuttle carrier (MEO host vehicle) configurations, and select a single configuration as the basis for the Facility design
- Select a single mission as a basis for definition of the Facility design
- Develop preliminary layouts of selected configuration of the Earth Observation Facility and to develop and refine a single design approach
- Prepare a functional description of the Facility, including interfaces and crew requirements
- Develop interface documentation in support of both interior and exterior equipment and Facility arrangements
- Identify crew activities and necessary skills
- Develop scale models of the Earth Observation Facility.

In Task 2 of the Manned Earth Observatory Study, nine reference missions were defined, based upon the identification of 30 experiments which were considered to be representative candidates for early Shuttle Sortie missions. The mission of highest priority, a pollution mission including nine experiments, was selected as a basis for design of the Manned Earth Observatory Facility.

A Baseline Facility configuration was first developed, with a sensor payload complement which would completely fulfill the scientific data collection requirements of the experiments, with 29 sensors comprising the instrumentation payload. This concept was then reviewed from the standpoint of costs of the mission. By elimination of one low-priority experiment, and by reduction of the number of sensors in the payload using the criteria of:

- a) Value of data obtained
- b) Status of sensor technology
- c) Costs and lead time for development of flight hardware,

a Facility configuration for a more austere Low-Cost Pollution mission was developed. Sixteen sensors comprise the payload for this mission.

The emphasis of the study was on the development of the Facility configuration for the latter mission.

This volume presents the results of Task 3 of the Manned Earth Observatory study. It includes the following:

- A discussion of early Earth Observations Facility concepts, with a description and comparison of candidate austere facility configurations
- The accommodation guidelines for the Shuttle Orbiter and Sortie Lab which was used in the study
- Conceptual designs of the Manned Earth Observatory for both the Baseline and Low-Cost Pollution missions
- Definition of the sensor payload for both the baseline and low-cost missions
- Sensor payload interface and support Facility subsystem requirements
- A definition of the functions of the crew during the selected mission
- Description of the Sortie Lab crew accommodations and common-core equipment
- Detailed data on sensor configuration and interfaces
- Layout drawings, defining the conceptual designs of the Manned Earth Observatory for both the Baseline and Low-Cost Pollution missions.

2.0 EARTH OBSERVATION FACILITY CONCEPTS

The principal objectives of Task 3 were to: devise conceptual designs of a Shuttle supported Manned Earth Observation Laboratory /Facility, construct a scale model of a selected MEO concept for a particular earth survey mission, and identify the principal interfaces between the payload equipment and the MEO host vehicle.

While a growth version of the MEO facility may accommodate essentially all the payload equipment for the complete list of derived earth survey experiments, the initial MEO facility may be designed, in the interest of economy, to support a portion of the total experiment program. Therefore, facility evolution is a design dimension where growth will be a product of time, money, new experiment needs, sensor development, crew size, and improved data management.

An initial MEO laboratory/facility is contemplated as a Space Shuttle supported, general purpose, manned, reusable vehicle that could perform a wide variety of earth observations studies on a series of short duration, low earth orbit, missions.

Present research programs in this discipline rely heavily on using unmanned satellites, such as the Earth Resources Technology Satellite (ERTS) or the proposed Small Applications Technology Satellite (SATS). The MEO laboratory would be a space facility in which man could effectively increase experiment efficiency by performing certain observations, modifications, instrumentation setup/calibration and limited equipment maintenance. In addition, man may monitor experiment progress and perform preliminary data evaluation to verify proper equipment functioning, and may terminate or redirect experiments to obtain the most desirable end result. The flexibility and unique capabilities of man as an experimenter in such a laboratory could add to the simplification of space experiments. This provides the basis for commonality in many of the support subsystems, thus reaping the benefits of reusability and reduced experiment costs. It is anticipated that such a laboratory could complement the various unmanned research programs in the earth observation disciplines by providing a facility for testing and evaluating portions of future automated experiments.

The use of the Space Shuttle as an orbiting platform for the MEO equipment will offer a substantially different concept in the acquisition of Earth Resources and Meteorology research data. The guidelines and assumptions which directed this study effort open the possibility of several laboratory options for configuration design, equipment layout, crew size, mission planning and program costs.

As a primary guideline, the MEO study has assumed that the host vehicle will be the NASA/MSFC-derived Sortie Lab. A detailed definition of the Sortie Lab and guidelines of its capabilities are presented in Section 3.2.

As a baseline, then, our goal was to show how the NASA/MSFC Sortie Lab (Pressurized Module + Pallet) could serve as the host vehicle for MEO missions. Sections 5.0 and 6.0 present conceptual layouts of payload equipment and crew functions for both full capability and low-cost MEO missions using the Sortie Lab operating within the Shuttle Orbiter cargo bay.

2.1 FACILITY GUIDELINES AND ASSUMPTIONS FOR AUSTERE MEO MISSIONS

In order to evaluate the feasibility of conducting MEO missions at austere levels of funding, which may be characteristic of early year operations, the study briefly examined alternate options of MEO equipment installation on Shuttle flights. Here, the Sortie Lab/Pallet was deleted as a candidate for the host vehicle. Instead, the payload equipment was installed on racks, or rings, or pallets in the Shuttle Orbiter bay with the MEO experiments being conducted from the Mission Specialist's Station on the Shuttle Orbiter flight deck.

The following guidelines were imposed on this preliminary review of austere, alternative, mission concepts of MEO payload accommodation:

- Safety - meets crew and Shuttle safety criteria.
- Minimum impact on Orbiter design.
- Modularity - for maximum flexibility of equipment use and location.
- Reuseable - no one-mission only concepts.
- Low design, fabrication, integration complexity.
- Standard material and hardware.
- Off-shelf components.
- Single, self-contained, removable units.

- Quick Orbiter loading and unloading capability.
- Easily transportable.
- Storable between flights with long life.
- Compact, using minimum payload bay space.
- Supported only by payload bay fittings.
- In-flight access to equipment.
- Relocatable in the Shuttle bay.
- EVA clearance - no obstruction to passage or vision of an EVA crewman.
- Remains attached to Shuttle - no free flying MEO payloads.

Plan - Against above guidelines, investigate MEO payload accommodation modes for Shuttle Sortie missions. Baseline mode is Sortie Lab. Do other modes offer lower cost potential without serious effects on the quality and quantity of MEO data?

2.2 ALTERNATIVE CONFIGURATION APPROACHES TO ACHIEVE AUSTERITY

Evaluation of payload accommodation concepts against the above guidelines for austere missions revealed the possibility of using one or more of the approaches shown in Table 2-1.

The basis for the derivation, selection, and design of the ring sector, equipment rack, and small pressurized container approaches to austere mission MEO payload accommodation is the TRW Systems Report "Concept of a Multi-Purpose Support System for Shuttle Sortie Experiments", Report Number 99900-H034-RO-00, dated January 1973.

2.3 COMPARISON OF CANDIDATE AUSTERE APPROACHES

The pallet only, ring sector, equipment racks, and small pressurized container concepts for installation of MEO payload equipment are compared on Table 2-2 against the guidelines, or criteria, of Section 2.1. Note that none of the concepts meets all criteria; however, preliminary examination shows the ring sector concept to have a slight advantage over the other candidates.

It should be pointed out here that any serious deviation from the full capability Sortie Lab (Pressurized Module + Pallet), as the host vehicle for MEO payload equipment, would result in reduced quantity and quality of acquired experiment data. The degree to which mission objectives

Table 2-1. MEO Configurations Baseline and Alternative Approaches for Austere Missions

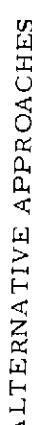
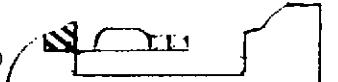
CONFIGURATION		DESCRIPTION
	SORTIE LAB (PRESSURIZED MODULE + PALLET)	MSFC's Basic Sortie Lab Pressurized Module (25-1/2 ft. length x 14 ft. dia.) with 30 ft. of payload pallet attached to the pressurized module. Full accommodation of MEO baseline mission experiment equipment.
		PALLET ONLY
		RING SECTORS
		EQUIPMENT RACKS ON ORBITER BULKHEAD AND SIDEWALLS
		PRESSURIZED CONTAINER + PLATFORM
		Location of the experimenter crew

Table 2-2. Comparison of Candidate Alternative Approaches to
MEO Payload Accommodation

Criteria	Alternative Approaches			
	Pallet Only	Ring Sectors	Equip. Racks	Press Cont.
Have no impact on Orbiter design	X	X	O	O
Be modular	X	X	X	X
Be reusable	X	X	X	X
Have low design complexity	X	X	X	O
Uses standard material and hardware	X	X	X	X
Sized for off-the-shelf subsystem hardware	O	O	X	O
Have minimum unused shelf volume (with minimum support equipment)	O	X	X	O
Be single, self-contained, removable unit	X	X	X	X
Uses small, otherwise unsuitable volumes	O	O	X	O
Have quick Orbiter loading and unloading capability	X	X	X	X
Have easy setup in GSE fixture	X	X	O	X
Be easily transportable with equipment installed	X	X	X	X
Be storable with long shelf life	X	X	X	O
Be located near each experiment	X	X	X	X
Be compact, using minimum payload bay space	O	X	X	O
Be supported only by payload bay fittings	X	X	X	O
Have emergency inflight access to equipment	X	X	X	X
Be relocateable in payload bay	X	X	X	X
Have EVA clearance with payload bay doors closed	X	X	X	X
Have capability to mount a small Sortie payload	X	X	X	X

Key: X - meets criteria
O - fails criteria

would be compromised by using austere concepts was not determined in this study. Justification for flying non-Sortie Lab MEO missions would seem to best fit the MEO program in the areas of: 1) aiding individual MEO sensor development and data taking technique development, 2) Shuttle Sortie missions where NASA desires to fly mixed discipline missions, 3) where NASA deems it effective to install a quick reaction payload element (such as a MEO ring sector or small pallet) on a Shuttle opportunity that suddenly appeared in the flight schedule, and 4) reduced budget MEO flights.

2.4 DESCRIPTION OF CANDIDATE AUSTERE PAYLOAD APPROACHES

The four alternative, austere, approaches to MEO payload accommodations are described below:

2.4.1 Orbiter Bay Pallet

A floor pallet installed in the Orbiter bay is a semi-monocoque panel, with an inner floor for mounting the equipment and an outer skin, curved to conform with the inside mold line configuration of the Orbiter's payload bay; the pallet extends across the full width of the bay. End formers, corner and intermediate longerons, skin frames, and tiedown fittings would complete the panel. A grid of the tiedown fittings would cover the floor for attachment of the many different configurations of MEO components. The pallet would be a modular design. One pallet would be used for a minimum MEO configuration package. Additional panels would be bolted together as required for larger MEO configurations, as well as for mounting an adapter to support experiments. Functionally, the floor pallet is suitable for locating the MEO components in a low position in the payload bay, between the floor and those experiments elevated to the mid-area or crown sections for operational purposes.

2.4.2 Segmented Ring Sectors

A segmented ring (Figure 2-1) can be designed with standard tubing edge members at the corners of a rectangular cross section. The modular arc segments would be built in various sizes. If a particular mission had enough MEO components to fill the racks in a 70-degree segment, then 45- and 30-degree stock ring segments would be bolted together to make up the unit. Functionally, the segmented ring rack is designed to occupy a minimum longitudinal (X-axis) length of the payload bay and at

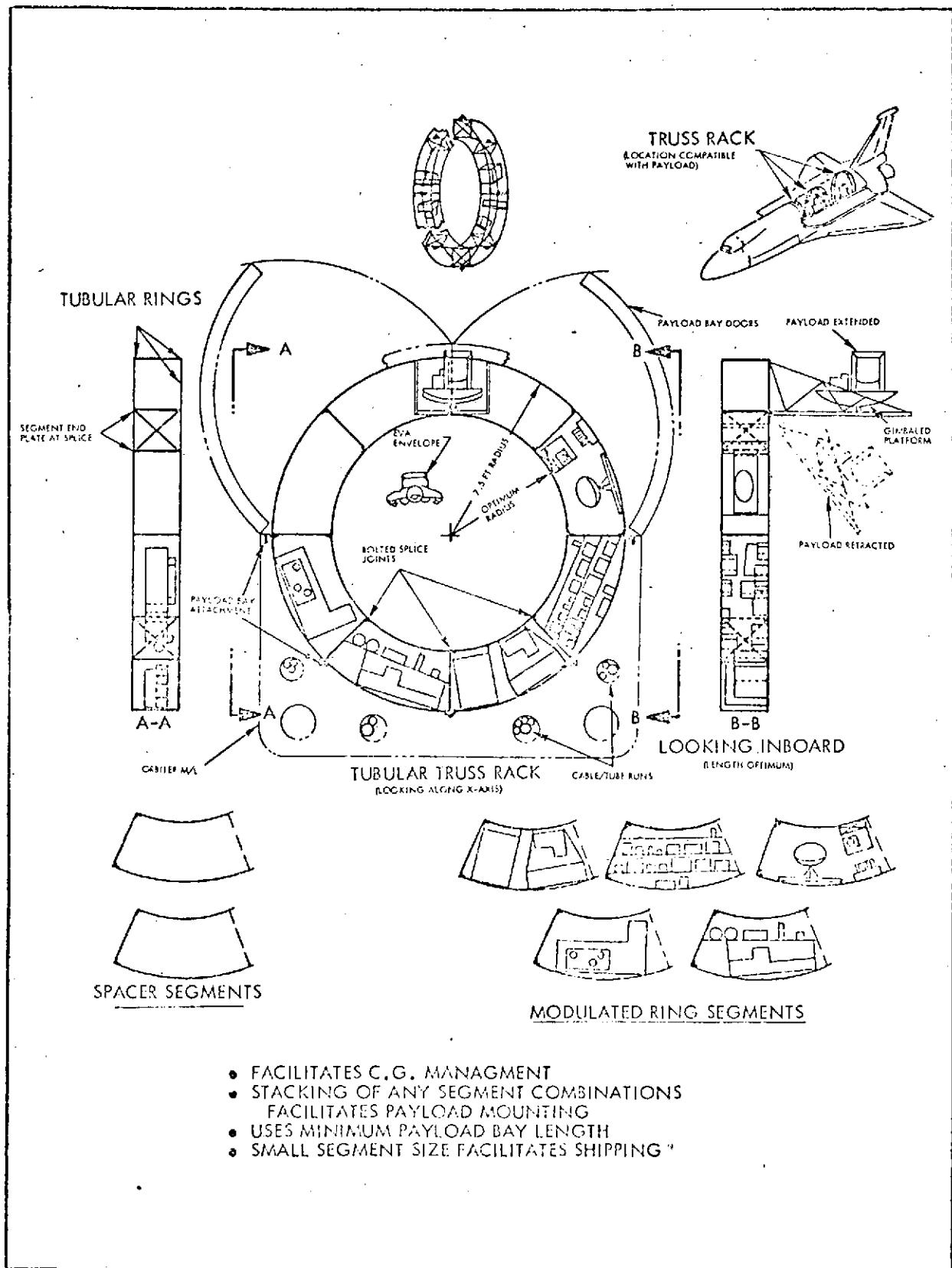


Figure 2-1. Segmented Ring Candidate

the same time be an easily removed or relocated unit with a complement of MEO equipment.

2.4.3 Equipment Racks

Orbiter bulkhead and sidewall equipment racks have standard tubing edge members, reinforced and cross-braced as needed. Slotted-hole edge member flanges would provide attaching points for bolting in the MEO components. For those missions that would utilize all of the shelf space on this rack for MEO equipment, the concept is the most attractive from a cost and weight viewpoint.

The racks are bolted to the primary skin frames of the Orbiter and are strategically positioned throughout the payload bay in available spaces.

The equipment racks would be the Air Transport Rack (ATR) devices used by the military and commercial aircraft industry to house avionic and mechanical equipment aboard airplanes. Figure 2-2 shows ATR type racks mounted on the Orbiter bay sidewall. They could also be mounted on the Orbiter bay fore or aft bulkheads.

Figure 2-3 depicts a modular pullout split chassis rack concept.

The major characteristics of Air Transport Racks are:

- Designed specifically for avionic use.
- Standardized dimensions and tolerances.
- Available from three aircraft companies and one independent manufacturer
 - Lockheed
 - McDonnell Douglas
 - Boeing
 - Hollingsead
- Six established size increments with choice of two lengths (long/short) for each.
- Widths range from 2 1/4 inches to 15 3/8 inches, standard height is 7 5/8 inches.
- Trays are available with pre-punched holes to accommodate between one and six connectors.

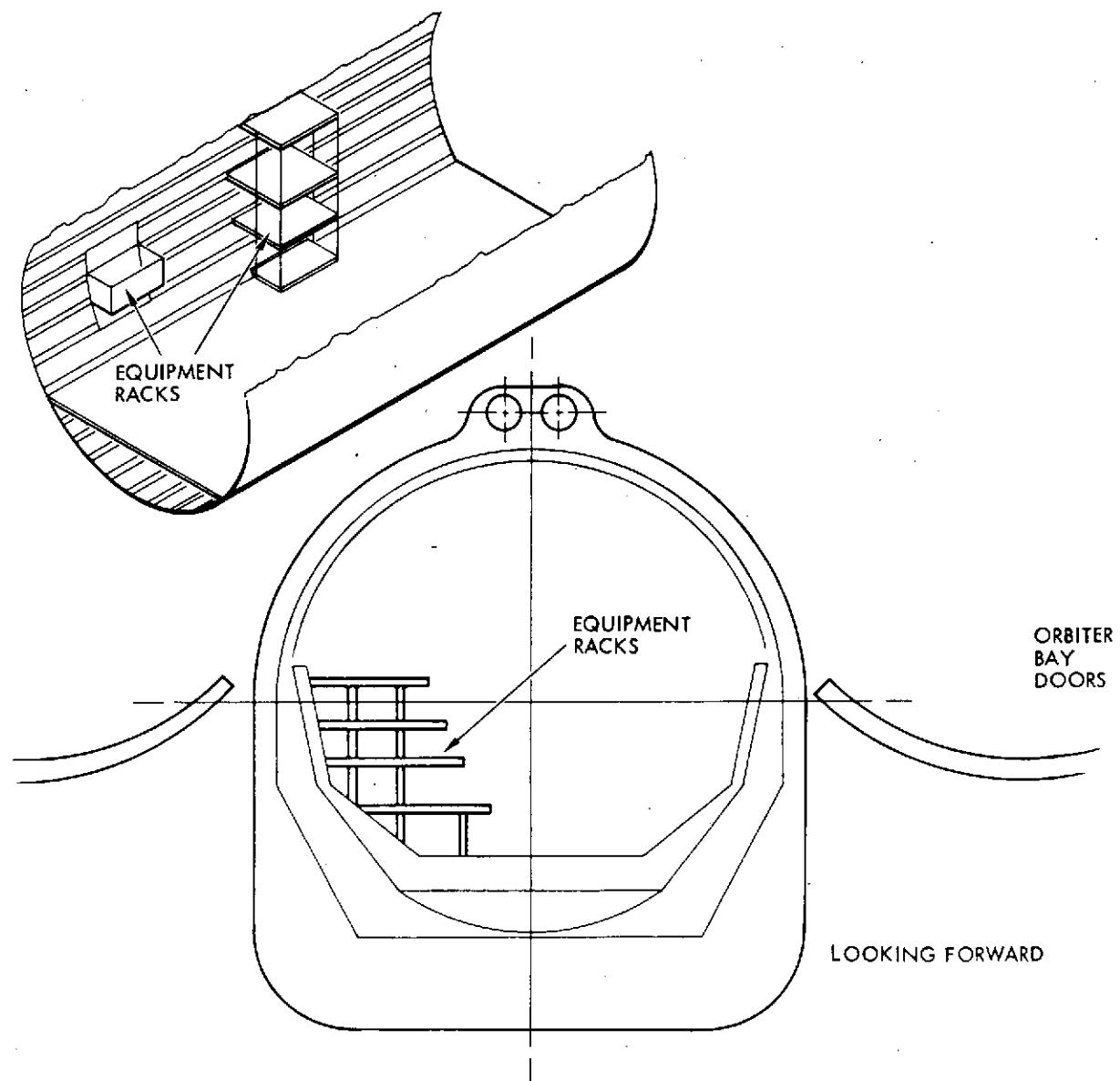


Figure 2-2. Bulkhead and Sidewall Racks

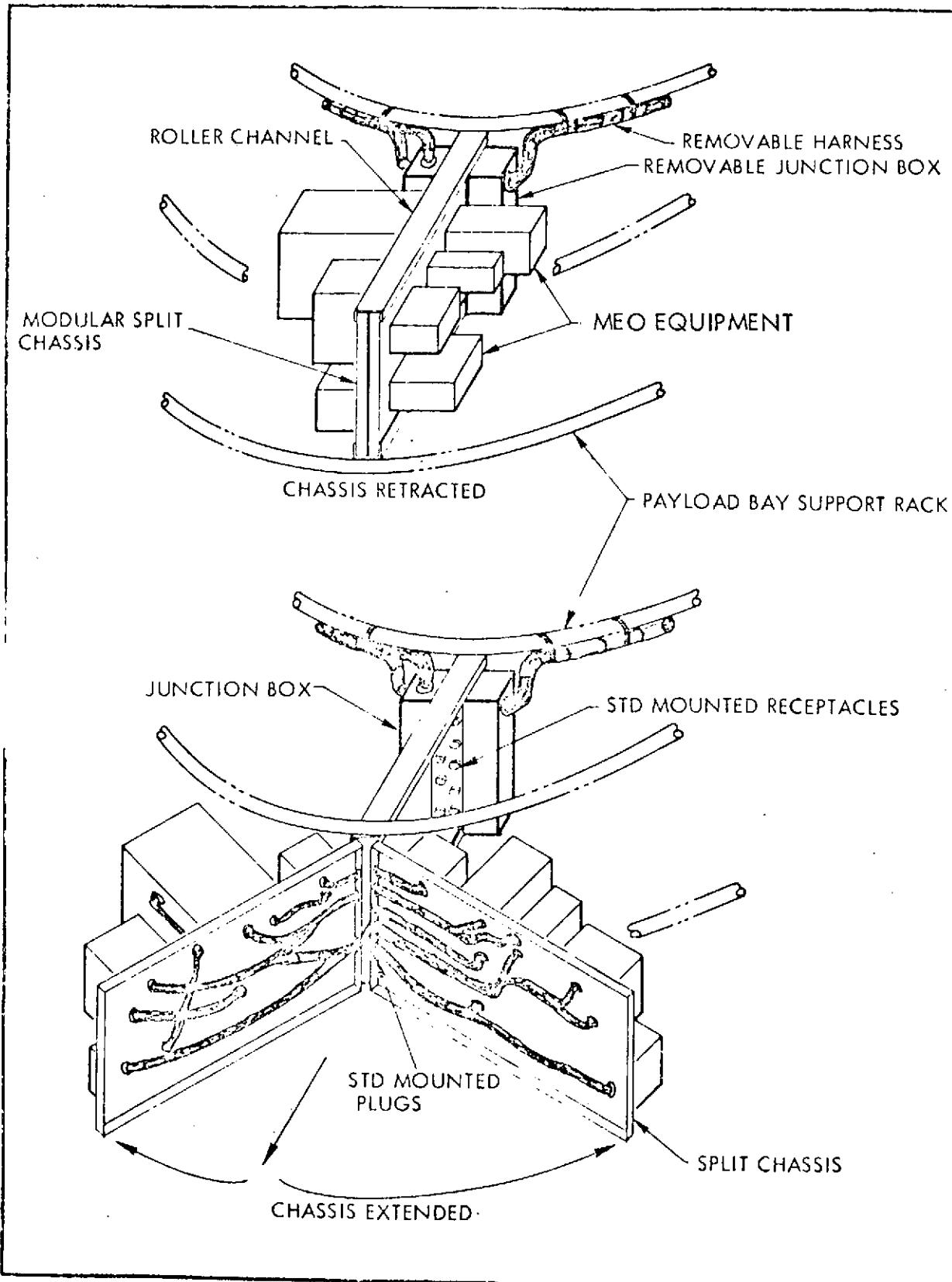


Figure 2-3. Equipment Rack - Modular Pullout Split Chassis

- Two connector types are standard cannon 'DPA', and 'DPD'.
- Tray-case capacity for useful contents ranges from $9\frac{1}{2}$ to $2\frac{1}{2}$ pounds to 60 ± 20 pounds.
- The structural concept will accommodate multiples of the largest size for specials.
- Four of the civil standard sizes are also standard for military aircraft and covered by Mil-C-172, cases, bases, mounting, and mounts vibration.
- System incorporates many desirable features including:
 - Tapered alignment pins to ensure precise engagement of connectors.
 - Latching handles that securely retain bases in trays.
 - Standard shock mounts for avionic environment.

2.4.4 Pressurized Container

Another candidate structure is a small pressurized can. Considerations for contamination control, heating and cooling with the pressurizing gas, minimizing the deterioration effect on film by out-gassing, etc., establishes a requirement for a pressurized structure. It is a semi-monocoque cylinder with dome ends. The internal structure design is, in part, dependent upon the method selected for opening the can which, in turn, is dependent upon the configuration, mass, and operational character of the equipment components in the can. There are at least two design choices for the internal structure. One would be a load-carrying cruciform beam that ties into the can structure at the orbiter's payload support fittings. The second would be a rack configuration tying in, internally, to the can frames as required.

Figure 2-4 displays the pressurized container concept.

2.4.5 Austere Payload Accommodation Options Summary

Although the segmented ring concept appears to be the most suitable mounting structure for MEO equipment, it is not unreasonable to consider any of the other four concepts acceptable for use exclusively or in conjunction with the ring. The floor pallet has a high criteria rating. It would be the prime candidate for mounting a relatively large complement of equipment and large experiments which require gimbaling. For this case, the floor pallet, MEO equipment, and the experiments are mechanized as a composite gimbaling mechanism.

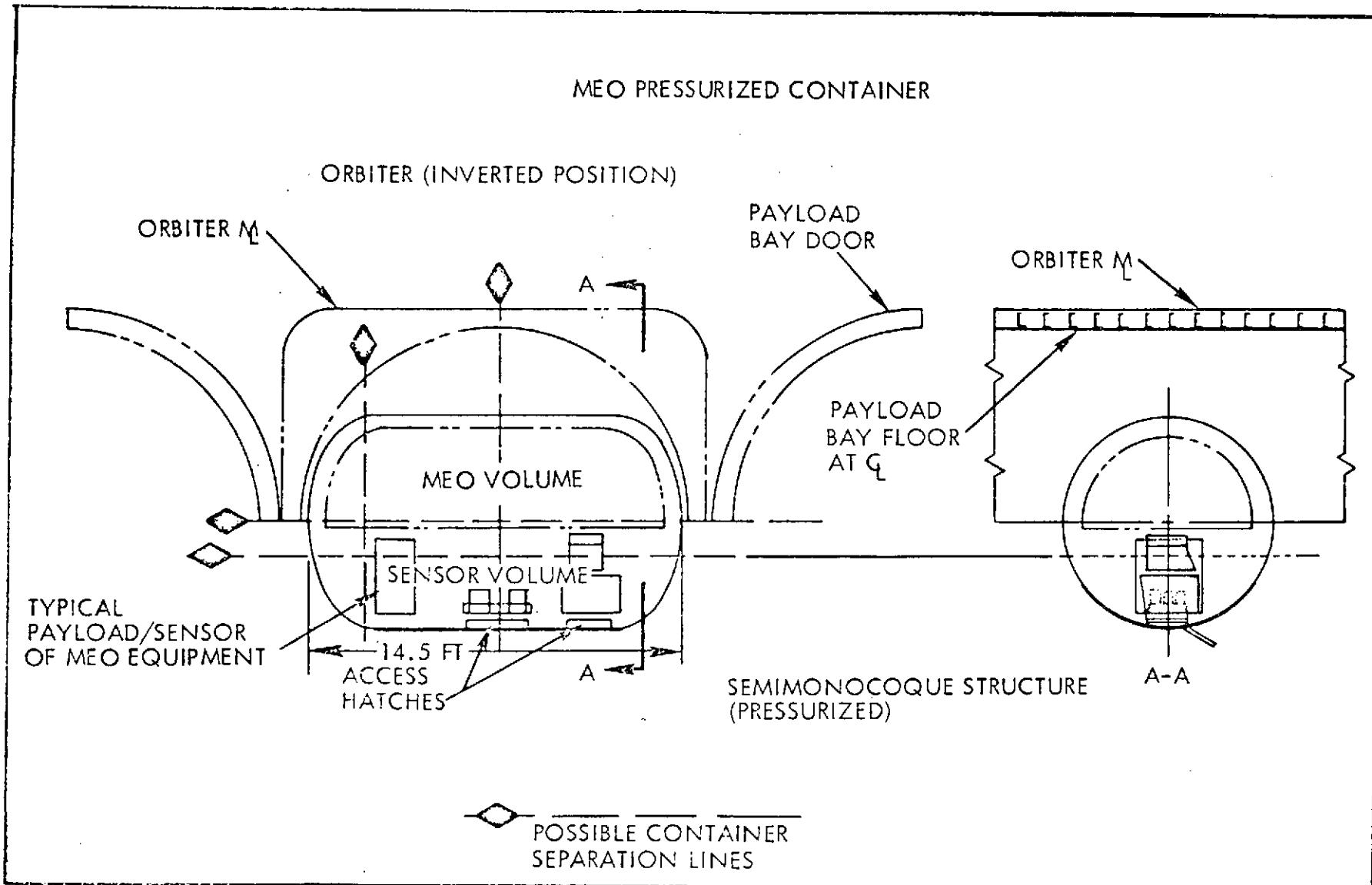


Figure 2-4. MEO Pressurized Container

Because by definition they are small, the ATR racks could be used to supplement the segmented ring. These racks would be particularly suitable for mounting a small but complete MEO subassembly, such as a small sensor and its support equipment.

The bulkhead or sidewall rack would be a strong contender if it became apparent that it could be used repeatedly with a high-volume loading factor. Being in proximity to the bulkhead gives it the advantage of leaving a maximum payload bay length unobstructed for other Shuttle mission objectives.

Although any of the structure types presented could be designed to provide a controlled environment for components, the pressurized can is, by design, the most suitable candidate for this purpose.

3.0 INTERFACE AND SUPPORT GUIDELINES

3.1 SHUTTLE ORBITER ACCOMMODATION GUIDELINES

A number of guidelines and assumptions pertaining to the design and performance of the Shuttle Orbiter impact on the interface and support requirements of the Sortie Lab. The following accommodation guidelines were considered during the course of this study: (See references end of Section 3.2)

- 1) Autonomy — The philosophy is to minimize the physical and operational interfaces so as to effect the least complexity and to maintain a baseline 14-day individual Shuttle turnaround potential (from orbital mission landing to launch readiness).
- 2) Orbiter Vehicle — The main fuselage of the Orbiter contains the crew compartment, a payload bay capable of accommodating single or multiple payloads up to 15 ft. (4.6 meters) diameter by 60 ft. (18.3 meters) long, support subsystems, an orbital maneuvering subsystem and the main propulsion system engines.
- 3) Flight Control/Crew Accommodations — The Orbiter crew compartment houses the flight crew, passengers, controls and displays, and most of the avionics and environmental control systems. Provisions for payload monitoring, passenger accommodation, electronics and environmental control/life support systems are located on a lower deck. The entire compartment provides a "shirtsleeve" environment for personnel and equipment. A crew of four can be accommodated in the pressurized cabin for a baseline mission. Up to six additional persons can be accommodated for shorter duration missions with minor changes to the cabin interior.

The Orbiter avionics system provides the functions for guidance, navigation, and control (for the Orbiter), communications, limited avionics performance monitoring and onboard checkout, electrical power distribution, conditioning and control, timing, and displays. Certain of these capabilities can be time shared for support of payloads from the payload compartment. These include capabilities for electrical power distribution and control, master caution and warning, navigational initialization, and communications. The Orbiter avionics system also provides computation capability for data processing and control for limited, functional end-to-end checkout of payloads.

- 4) Payload Handling — During orbital operations, payloads can be docked to the Orbiter, remain within the payload bay, or be deployed and released from the Orbiter. Airlocks and/or hatches are provided to permit "shirtsleeve" access to pressurized payloads and pressure suit access to the unpressurized payload bay.

- 5) Orbiter Operational Use — The Space Shuttle can support a Sortie Lab/Pallet Science and Applications activity in orbit. (Information regarding the Sortie Lab is presented in Section 3.2.)
- 6) Shuttle Performance — The basic payload capability is baseline as follows:
 - Total Usable Volume — 15 ft. (4.6 m) diameter x 60 ft. (18.3 m) long.
 - Total available payload for due east orbit — 65,000 lb. (29,500 kg).
 - Total available payload for polar orbit — 40,000 lb. (18,100 kg).
- 7) Mission Characteristics — The nominal time from lift-off to Orbiter return is seven days. (This gives approximately 6.5 days for on-orbit operations with the Sortie Lab.) Shorter duration missions may be accommodated if desired. Missions up to 30 days are planned to evolve as the program and requirements indicate. Missions in excess of seven days will have the weight of the extra expendables charged against the payload.

Mission requirements will dictate the preselection of inclination angles for Shuttle insertion into orbit. Orbits of 28.5 to 55 degrees inclination and altitudes of 100 to several hundred nautical miles are attainable from the KSC launch site. The Western Test Range will be required and utilized for polar and near-polar orbits. The estimated date for the availability of the WTR is 1983.

For planning purposes, 80 percent of basic payload capability is assumed. The total weights of the major carrier elements are estimated to be:

Standard Sortie Lab and Pallet with Systems: 20,000 lbs
(9,100 kg)

- 8) Selected Resources Services —

- Communication Links (Space Shuttle-P/L-Ground)

25 Kb/sec dedicated
256 Kb/sec maximum

- Electrical Power —

Average Available — 7 Kw

Peak — 10 Kw for 6 minutes

Peaking Power Kit Available

- **Stability and Control** — The Orbiter is capable of pointing a payload continuously for one orbit every other orbit for one 24-hour period per mission at any ground, celestial, or orbital object within ± 0.5 degree.

The payload stabilization capability of the Orbiter has been defined as follows:

	With Baseline RCS System (1000 lbs.)	With 1000 lbs. and 25 lbs. RCS System (under study)
Roll	0.0223 deg/sec	0.0023 deg/sec
Pitch	0.0143 deg/sec	0.0009 deg/sec
Yaw	0.0068 deg/sec	0.0004 deg/sec

The capabilities and characteristics of the Shuttle Orbiter will become available over a period of time as development proceeds. The estimated schedule availability of several Shuttle capabilities of particular interest to earth observations are shown in Table 3-1.

Table 3-1. Shuttle Schedule in Terms of Performance Capability

Configuration	Inclination/ Altitude	Wt. in # (Kg)	Fiscal Year				
			79	80	81	82	83
Shuttle/Sortie Lab	28.5°/250 nmi	12,000-20,000 (5450-9100)			X		
Shuttle/Sortie Lab	Polar/250 nmi	12,000-20,000 (5450-9100)					X

3.2 SORTIE LAB ACCOMMODATION GUIDELINES

The Sortie Lab and/or pallet comprise the basic Space Shuttle experiment carrier system and effect the composite interface with the Space Shuttle through standardized interfaces. The payload crew (nominally two available on-orbit) eat and sleep in the Orbiter cabin and enter the Sortie Lab for direct experiment operations. Free movement back and forth is envisioned with compartments separated by a hatch and a short tunnel. In the case of a pallet-only configuration, the crew would nominally remain in the Orbiter cabin and operate experiment payloads from a special payload-provided console located in the Orbiter cabin. An EVA airlock will be available on the Shuttle, with the location relative to the cargo bay yet to be determined.

A number of guidelines and assumptions (see references end of Section 3.2) which describe various characteristics and capabilities of the Sortie Lab were considered during the course of this study. They include the following:

- 1) Basic Sortie Lab Description — The basic Sortie Lab is a pressurized vessel consisting of a cylindrical portion and two removable end bulkheads. It provides a working environment for the crew and accommodations for conducting experiments in orbit.

It has a structural diameter of 14 ft. (4.27 m) and a cylindrical length of 20 ft. (6.1 m). Together with 33 in. (0.8 m) deep bulkheads on either end, the total length is 25.5 ft. (7.8 m).

The Sortie Lab subsystems and general experiment support equipment occupy a portion of the forward half of the available mounting space (above and below the floor). The remaining space is available for experiment and equipment installation.

The Standard Lab includes a crew station console(s) for monitoring the operation of the module systems and for experiment operation, a work bench, standard equipment racks for carry-on electronics, and a crew system cabinet for crew personal items.

The Lab design has standard provisions for thermal control, electrical power, data management, equipment support, storage or accommodation space for experiments, standardized connectors for power, data, vacuum, and lighting, viewports and structural attachment fittings for standard supplementary equipment such as experiment airlocks, large view windows, or pallets which are planned elements of the program.

The basic lab design will also be configured to take additional mission-oriented equipment, allowing for the effective accommodation of varied types of experiments or a tailoring for specialized scientific disciplines.

- 2) Pallet Description — The pallet is a variable length platform on which experiments and supporting equipment are mounted and launched to orbit inside the Shuttle payload bay. Experiments can be accommodated that vary in size up to 10 ft. (3.1 m) by 56 ft. 8 in. (17.3 m) long. Experiments are conducted with the pallet inside the Shuttle payload bay. The pallet may be flown with or without the lab.
- 3) Autonomy — The Sortie Lab will make efficient use of Shuttle-provided utility support (i. e., power, communications, environmental control, etc.) consistent with a simple module-to-orbiter interface and with minimal mutual interference during turnaround activities.
- 4) Weight — The design weight of the Sortie Lab and pallet is 20,000 lbs. (9,100 kg). The Sortie Lab can accommodate a payload of 12,000 lbs. (5,450 kg), which includes experiment hardware, experiment-peculiar integration equipment, and all payload chargeable payload specialists and their equipment. Both the pallet and the pressurized module are independently capable of accommodating the 12,000 lb. payload or any combination up to the 12,000 lb. payload.
- 5) Dimensions/Envelope —
 - Sortie Lab plus pallet will not exceed an overall length of 45 ft. (13.7 m) for a deployable position.
 - Maximum external diameter of lab and pallet is 14 ft. (4.25 m).
 - The envelope (payload bay) of the orbiter is 15 ft. (4.6 m) diameter by 60 ft. (18.3 m) long.
 - The Sortie Lab and pallet remain attached to the Shuttle Orbiter.
- 6) Design Life — Fifty 7-day missions with refurbishment.
- 7) Crew Size — The baseline is four payload crewmen with a minimum of two and a maximum of six.
- 8) Mission Duration — Seven days or less, with growth to 30 days.
- 9) Reliability — 0.95 probability of mission success.
- 10) EVA — EVA operations are to be minimized. If required, EVA is via the Orbiter.

11) Subsystems — Available subsystems are to be used where cost effective.

- Communications: 25 K bits/sec (S-band and VHF) via the Orbiter; intercom voice to Orbiter flight deck.
- Data Management: Primary mode is on-board data recording, at from 2 to 10^5 K bits/sec.
- Electrical Power: Average available — 7 Kw
Peak — 10 Kw for six minutes
Peaking Power Kit Available.
- Environmental Control: Two-Gas System O_2 - N_2 at 14.7 psia;
Radiator Heat Rejection — 8.5 Kw;
Experiment Cooling — 5 Kw.
- Stability/Attitude Control: Shuttle provides 0.5 degree and 0.01 degree/sec up to 12 hours/mission. Special payload stability and control requirements above the Shuttle-provided capabilities will be provided by payload integration or payload integral equipment.
- Man/System Integration: 12-hour shift in Sortie Lab and 12-hour rest in Orbiter; sleep, galley, personal hygiene in Orbiter.

12) Support Equipment — Support equipment will include the following: Equipment racks, work bench(es), observation ports, air locks, controls/displays, general computer, TV, crew support.

13) Maintenance — All in-orbit maintenance and servicing activities will be accomplished in a shirtsleeve environment to the maximum practical extent. No scheduled in-flight maintenance during the 7-day mission. Unscheduled in-flight maintenance will be limited to minor adjustments and repairs.

14) Instrumentation/Equipment

- To the extent that it is compatible with the Space Shuttle/payload carrier operations, the design of scientific instrumentation and support equipment should permit both in-orbit replacement and retro-fitting, and return to earth for possible refurbishment and updating.
- Use of "off the shelf" hardware will be considered when it minimizes development costs and adheres to the required safety standards.
- Use of advanced state-of-art hardware will be considered when it minimizes development costs and adheres to required safety standards.

15) The Initial Operating Capability (IOC) date for Shuttle missions is assumed to be 1979.

Reference Documentation for Shuttle Orbiter and Sortie Lab Accommodation Guidelines and Assumptions (Sections 3.1 and 3.2):

- 3-1 Assumptions and Guidelines Contained in Phase A Study Plan for "Mission Requirements for a Manned Earth Observatory," TRW Systems, Contract No. NAS8-28013, Revised August 12, 1972.
- 3-2 Space Shuttle Program Requirements Document, Level 1, Revision 4, NASA Headquarters, April 21, 1972.
- 3-3 Payload Design Requirements for Shuttle/Payload Interface, NASA/MSFC, May 4, 1972.
- 3-4 Space Shuttle Performance Capabilities, Revision 1, MSC-04813, NASA/MSC, May 16, 1972.
- 3-5 Space Shuttle Baseline Accommodations for Payloads, MSC-06900, NASA/MSC, June 27, 1972.
- 3-6 Proceedings of the Space Shuttle Sortie Workshop, Volume I, Policy and System Characteristics, Held at NASA/GSFC, July 31-August 4, 1972.
- 3-7 Space Shuttle Presentation to Earth Observations Working Group by NASA Headquarters at NASA/GSFC, November 16, 1972.
- 3-8 Sortie Lab Briefing to Earth Observations Working Group, by NASA Headquarters at NASA/GSFC, November 16, 1972.
- 3-9 Shuttle Earth Observation Working Group, Interim Report, NASA/GSFC, Revised, February 14, 1973.
- 3-10 Sortie Can Conceptual Design, ASR-PD-DO-72-2, NASA/MSFC, March 1, 1972.
- 3-11 Sortie Lab Conceptual Baseline Definition, NASA/MSFC, July 25, 1972.
- 3-12 Sortie Lab Guidelines and Constraints, Level 1, Rev. No. 1, NASA Headquarters/OMSF, August 15, 1972.
- 3-13 Sortie Lab Design Requirements, NASA/MSFC, December 1, 1972.

4.0 SENSOR PAYLOAD - BASELINE AND LOW-COST POLLUTION MISSIONS

The nine experiments, in order of priority, which were defined during Task 2 to form the Baseline Pollution mission are listed in Figures 4-1 and 4-2 in conjunction with the sensors which have been selected to support the objectives of the experiments.

The sensor payload for this mission consists of 29 sensors, which may be categorized as follows:

- Optical viewers, for use by the crew within the Sortie Lab for sighting and orientation
- An r.f. data collection system, to obtain correlative data from data collection platforms on the surface of the earth
- Film cameras, which perform the functions of target area identification, cartographic and topographic mapping, and obtaining multiband monochrome, color, and false color imagery, with various degrees of spatial resolution and scale numbers.
- A multispectral imaging line scanner, to obtain multiband imagery from the visual to the thermal infrared spectral range
- An infrared spectrometer, for geological research
- Synthetic aperture radars, for pollution identification, mapping, and agricultural applications.
- A passive microwave radiometer, used primarily to obtain correlative meteorological data in support of atmospheric pollution measurements
- A laser altimeter/scatterometer, which can be used to measure water surface roughness, indicative of surface pollution (oil slicks, etc.)
- Imaging spectrometers, for identification of water pollution through measurement of spectral signatures in the near-visual range of the spectrum
- Imaging IR radiometers, to obtain imagery of water surfaces in the thermal infrared range, for pollutant identification
- A star-tracking instrument, to obtain meteorological data on the global distribution of atmospheric density.
- Air pollution sensors, for measurement of the distribution and concentration of both gaseous and particulate air pollutants, in addition to measurement of the composition of the upper atmosphere

X = USED IN BOTH BASELINE AND LOW COST MISSIONS
 O = USED IN BASELINE MISSION ONLY

NO.	TYPE	SENSOR	EXPERIMENTS										PRIORITY
			AIR POLLUTION	REGIONAL WATER POLLUTION	LAKE EUTROPHICATION	COASTAL PROCESSES	LAND GEOMORPHIC	INTERNATIONAL SURVEY	WILDLIFE ECOSYSTEM	GEOLOGIC AND MAPPING	INTERNATIONAL FEASIBILITY	STELLAR ANALYSIS	
32	OPTICAL VIEWERS	WIDE ANGLE VIEWER	X	X	X	X	X	X	X	X	X		
1		TRACKING TELESCOPE	X	X	X	X	X	X	X	X	X		
33	RF DCS	DATA COLLECTION SYSTEM	X	X	X	X	X	X					
2	FILM CAMERAS	POINTABLE IDENTIFICATION CAMERA 70 MM FILM	X	X	X	X	X	X	X	X	X		
3		PANORAMIC CAMERA (5 IN. FILM)				O	O		O	O			
4		WIDE ANGLE FRAMING CAMERA 24 x 48 CM (9 x 18 IN.) FILM				O	O		O	O			
5		MULTISPECTRAL CAMERA SYSTEM 24 x 24 CM (9 x 9 IN.) FILM		X	X	X		X	X	X			
6		HIGH RESOLUTION MULTISPECTRAL CAMERA SYSTEM (70 MM FILM)		X	X								
7		MULTIRESOLUTION FRAMING CAMERA SYSTEM 24 x 24 CM (9 x 9 IN.) FILM			X	X	X	X	X	X	X		
8	MULTISPECTRAL IMAGING LINE SCANNER	HIGH RESOLUTION WIDEBAND MULTISPECTRAL SCANNER (20 SPECTRAL BANDS)			X	X	X	X	X	X			
9	IR SPECTROMETER	LWIR SPECTROMETER (6.2 - 15.5 μ , 0.4 - 2.4 μ)				O			O				
10	SYNTHETIC APERTURE RADARS	WIDEBAND SYNTHETIC APERTURE RADAR	O										
11		MULTIFREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR			O				O	O			
29	PASSIVE MICROWAVE	PASSIVE MICROWAVE RADIOMETER (PMMR) (5 BANDS, 4.99 - 37 GHz)	O		O				O				

Figure 4-1. Experiments and Sensors
 (Baseline and Low-Cost Missions (1 of 2)

EXPERIMENTS

PRIORITY

NO.	TYPE	SENSOR	1			2		3	
			AIR POLLUTION	REGIONAL WATER POLLUTION	LAKE EUTROPHICATION	COASTAL AND GEOMORPHIC PROCESSES	INTERNATIONAL URBAN SURVEY	WILDLIFE/ECOSYSTEM STUDIES	GEOLOGIC AND TOPOGRAPHIC MAPPING
12	LASER	LASER ALTIMETER/SCATTEROMETER	O						
13	IMAGING SPECTROMETERS (WATER POLLUTION)	VISIBLE IMAGING SPECTROMETER	X	X					
15		HIGH RESOLUTION VISIBLE IMAGING SPECTROMETER	O	O					
14	IMAGING IR RADIOMETERS (WATER POLLUTION)	IR MULTISPECTRAL MECHANICAL SCANNER	X	X					
16		HIGH RESOLUTION IR MULTISPECTRAL SCANNER	O	O					
18	STAR TRACKER	STAR TRACKING TELESCOPE						O	
20	AIR POLLUTION SENSORS	VISIBLE RADIATION POLARIMETER	X						
19		UV UPPER ATMOSPHERE SOUNDER	O						
26		ADVANCED LIMB RADIANCE INVERSION RADIOMETER	X						
23		CARBON MONOXIDE POLLUTION EXPERIMENT	X						
21		AIR POLLUTION CORRELATION SPECTROMETER	X						
22		HIGH SPEED INTERFEROMETER	X						
25		REMOTE GAS FILTER CORRELATION ANALYZER	X						
27	IR RADIOMETERS (CORRELATIVE DATA - AIR POLLUTION)	TIROS-N ADVANCED VERY HIGH RESOLUTION RADIOMETER	O						
28		TIROS-N OPERATIONAL VERTICAL SOUNDER	O						

Figure 4-2. Experiments and Sensors
(Baseline and Low-Cost Missions) (2 of 2)

- IR radiometers, to obtain correlative data (cloud cover and atmospheric temperature profiles) in support of air pollution measurements.

For the Baseline Pollution mission, which was configured without emphasis on mission costs, a complement of 29 sensors was identified to obtain the measurements required to support the scientific objectives of the nine experiments.

Both the experiments and sensor payload were then reviewed more critically, in order to define a more austere mission with emphasis on reduction of the mission costs.

One low-priority experiment, the Stellar Occultation experiment, was deleted. The sensors were then evaluated using the following criteria:

- a) Value of data obtained to the experiment
- b) Maturity of development, supporting research and technology required for demonstration of feasibility, and developmental lead time
- c) Costs of sensor development.

In addition, the use of alternate sensors was considered.

This resulted in a reduction of the sensor payload from 29 to 16 instruments. The resulting complement of sensors for the Low-Cost Pollution mission is also illustrated in Figures 4.1 and 4.2.

Note that the two optical viewers and the Pointable Identification Camera have been identified as Common-Core Experiment Sensors, being used in all of the experiments for both missions. The balance of the sensors are considered to be experiment-unique.

4.1 SENSOR UTILIZATION

4.1.1 Sensor Utilization – Baseline Pollution Mission

The specific utilization of the 29 sensors comprising the payload for the Baseline Pollution mission is illustrated in Table 4-1. A discussion of the specific use of each follows.

Optical Viewers – The Wide Angle Viewer, used for general-purpose viewing of broad areas, has three optical fields of view (110, 55, and 28 degrees square) in addition to full azimuth freedom and elevation gimballing over a range of 0 to 60 degrees from the nadir. This

Table 4-1. Sensor Utilization, Baseline Mission

SENSOR NO.	TYPE	SENSOR	UTILIZATION
32 1	OPTICAL VIEWERS	WIDE ANGLE VIEWER	LARGE AREA VIEWING AND ORIENTATION
		TRACKING TELESCOPE	HIGH RESOLUTION VIEWING - SPECIFIC TARGETS
33	RF DCS	DATA COLLECTION SYSTEM	TO OBTAIN DATA FROM SURFACE PLATFORMS
2 3 4 5 6 7	FILM CAMERAS	POINTABLE IDENTIFICATION CAMERA 73 MM FILM	LARGE AREA TARGET IDENTIFICATION
		PANORAMIC CAMERA (5 IN. FILM)	HIGH RESOLUTION STEREO PHOTOGRAPHY-TOPOGRAPHIC MAPPING
		WIDE ANGLE FRAMING CAMERA 24 X 48 CM. (9 X 18 IN.) FILM	CARTOGRAPHIC AND TOPOGRAPHIC MAPPING WITH HIGH GEOMETRIC FIDELITY
		MULTISPECTRAL CAMERA SYSTEM 24 X 24 CM. (9 X 9 IN.) FILM	MULTIBAND PHOTOGRAPHY - POLLUTANT IDENTIFICATION ALSO FOR AGRICULTURAL, FORESTRY, GELOGIC APPLICATIONS
		HIGH RESOLUTION MULTISPECTRAL CAMERA SYSTEM (70 MM FILM)	HIGH RESOLUTION MULTIBAND PHOTOGRAPHY-SPECIFIC TARGETS - POLLUTANT IDENTIFICATION
		MULTIRESOLUTION FRAMING CAMERA SYSTEM 24 X 24 CM (9 X 9 IN.) FILM	SIMULTANEOUS FALSE COLOR IR PHOTOGRAPHY WITH THREE STAGES OF RESOLUTION
		MULTISPECTRAL IMAGING LINE SCANNER	MULTIBAND IMAGERY-VISUAL, MID-IR, THERMAL IR RANGES AGRICULTURE, FORESTRY, GEOLOGICAL APPLICATIONS
8	MULTISPECTRAL IMAGING LINE SCANNER	HIGH RESOLUTION WIDEBAND MULTISPECTRAL SCANNER (20 SPECTRAL BANDS)	MULTIBAND IMAGERY-VISUAL, MID-IR, THERMAL IR RANGES AGRICULTURE, FORESTRY, GEOLOGICAL APPLICATIONS
9	IR SPECTROMETER	LWIR SPECTROMETER (6.2 - 15.5 μ , 0.4 - 2.4 μ)	GELOGIC SURVEYS - IDENTIFICATION OF TYPES OF ROCKS, SEDIMENTS, AND SOILS
10 11	SYNTHETIC APERTURE RADARS	WIDEBAND SYNTHETIC APERTURE RADAR	ICE FIELD MAPPING - DETERMINATION OF OCEAN POLLUTION AND SURFACE WIND PATTERNS
		MULTIFREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR	IDENTIFICATION OF CROPS AND SOIL CONDITIONS BY BACKSCATTER CHARACTERISTICS
29	PASSIVE MICROWAVE	PASSIVE MICROWAVE RADIOMETER (PMMR) (5 BANDS, 4.99 - 37 GHZ)	PRECIPITATION SURVEY, SEA SURFACE TEMPERATURE, SURFACE ROUGHNESS AND WIND
12	LASER	LASER ALTIMETER/SCATTEROMETER	OCEAN SURFACE ROUGHNESS AND WIND, PROFILING OF MOUNTAINOUS TERRAIN AND CHLOROPHYLL DEPTH
13 15	IMAGING SPECTROMETERS (WATER POLLUTION)	VISIBLE IMAGING SPECTROMETER	WATER POLLUTION - IDENTIFICATION AND PATTERNS (WIDE AREA - LOW RESOLUTION)
		HIGH RESOLUTION VISIBLE IMAGING SPECTROMETER	WATER POLLUTION - IDENTIFICATION AND PATTERNS (SMALL AREA - HIGH RESOLUTION)
14 16	IMAGING IR RADIOMETERS (WATER POLLUTION)	IR MULTISPECTRAL MECHANICAL SCANNER	WATER POLLUTION - THERMAL PATTERNS (WIDE AREA - LOW RESOLUTION)
		HIGH RESOLUTION IR MULTISPECTRAL SCANNER	WATER POLLUTION - THERMAL PATTERNS (SMALL AREA - HIGH RESOLUTION)
18	STAR TRACKER	STAR TRACKING TELESCOPE	METEOROLOGY - MEASUREMENT OF ATMOSPHERIC DENSITY BY STAR OCCULTATION
20 19 26 23 21 22 25	AIR POLLUTION SENSORS	VISIBLE RADIATION POLARIMETER	AIR POLLUTION (PARTICULATE) - TYPE AND DISTRIBUTION
		UV UPPER ATMOSPHERE SOUNDER	MEASUREMENT OF OZONE AND NITROUS OXIDE CONTENT OF UPPER ATMOSPHERE
		ADVANCED LIMB RADIANCE INVERSION RADIOMETER	DISTRIBUTION OF TEMPERATURE, OZONE, H ₂ O, NO _x , AND SULFATE AEROSOLS (TROPOSPHERE TO MESOSPHERE)
		CARBON MONOXIDE POLLUTION EXPERIMENT	AIR POLLUTION (GASEOUS) - GLOBAL AND VERTICAL DISTRIBUTION - NO _x , CO _x , SO _x , NH ₃
		AIR POLLUTION CORRELATION	AIR POLLUTION (GASEOUS) - GLOBAL DISTRIBUTION SO ₂ AND NO ₂
		HIGH SPEED INTERFEROMETER	AIR POLLUTION (GASEOUS) - GLOBAL AND VERTICAL DISTRIBUTION - NO _x , CO _x , SO _x , NH ₃
		REMOTE GAS FILTER CORRELATION ANALYZER	AIR POLLUTION (GASEOUS) - GLOBAL DISTRIBUTION NO _x , CO _x , SO _x , NH ₃
27 28	IR RADIOMETERS (CORRELATIVE DATA-AIR POLLUTION)	TIROS-N ADVANCED VERY HIGH RESOLUTION RADIOMETER	MEASUREMENT OF EXTENT OF CLOUD COVER - DAY AND NIGHT (CORRELATIVE DATA FOR AIR POLLUTION SENSORS)
		TIROS-N OPERATIONAL VERTICAL SOUNDER SOUNDER	VERTICAL TEMPERATURE PROFILING OF THE ATMOSPHERE (CORRELATIVE DATA FOR AIR POLLUTION SENSORS)

instrument is intended for large area viewing of the terrain by the crew. In addition to visual sighting, a CCTV display is provided within the Sortie Lab. A specialized usage is that of observing lightning flashes accompanying thunderstorm activity, using a hydrogen-alpha line optical filter which can be inserted into the eyepiece mechanism.

The Tracking Telescope will provide for telephoto (narrow-angle) viewing of specific targets, with optical fields of view of 0.5 and 4 degrees, with magnifications of 124 and 16. Gimballing over a wide range in roll and pitch is provided. Ground resolution will be 5 meters/optical line-pair at maximum magnification. Slaving of any of the gimballed sensors of the payload to the tracking telescope will be provided, to obtain data on specific targets of opportunity.

RF Data Collection System — The primary purpose of this system is to obtain correlative data supporting the experiment objectives from data collection platforms on the surface of the earth.

Film Cameras — The Pointable Identification Camera, using both panchromatic and color film with a 70 mm format, will be used for general identification photography of broad target areas. Two-axis gimballing will be provided for pointing of the camera.

The Panoramic Camera, using 5 x 45 in. film, will be used to obtain either high resolution vertical or stereo panoramic photography. The cross-track field of view is 120 degrees, and stereo photography is obtained by nodding the camera about the pitch axis through an angle of +12.5 degrees. This camera has been previously used in the Apollo 15, 16, and 17 missions, in which high resolution topographic mapping of the lunar surface was accomplished.

The Wide Angle Framing Camera, of metric quality and using 9 x 18 inch film, has been recommended by the U. S. Dept. of Interior for use with the Panoramic Camera for mapping. The primary feature of this camera is the high geometric fidelity of the imagery, enabling cartographic mapping to be performed. In addition, the wide field of view in the along-track direction (74 degrees) permits stereo photography to be obtained.

The Multispectral Camera System, using a group of six metric cameras and 9 x 9 inch film, will obtain multiband imagery on black and white film in four spectral bands, in addition to color and false color photography with the other two cameras. A primary application of this camera is the identification of the areal extent of pollutants by analysis of the narrow-band monochrome and false color imagery. In addition this camera system has broad applications in agricultural, forestry, and geologic research.

The High Resolution Multispectral Camera System, using telephoto optics with a field of view of 1.75 degrees, can be pointed toward specific areas of interest to obtain multiband monochrome, color, and false color imagery. Ground coverage will be approximately 6 x 6 n. mi. at nadir, with a ground resolution of 6 meters/optical line-pair.

The applications are the same as those identified for the Multispectral Camera System.

The Multiresolution Framing Camera System, using three bore sighted 9 x 9 inch formats cameras with lenses of 18, 36, and 72 inch focal length, will be used for simultaneous observations of the same target area with three different values of ground resolution. Using false color film in all three cameras, this will enable experimentation to determine the resolution requirements for future observations in the experimental areas of lake eutrophication, coastal and geomorphic processes, urban surveys, wildlife ecosystem studies, and geologic mapping.

Multispectral Imaging Line Scanner — This instrument will provide multispectral imagery with relatively high ground resolution (30 or 60 meters) in 20 spectral bands from the visual to the thermal infrared, obtaining imagery beyond the spectral range of film cameras. Primary applications are in agricultural, forestry, and geological applications.

IR Spectrometer — The LWIR Spectrometer, similar to the Skylab S-192 instrument, is intended primarily for geologic research. Sensitive over the spectral ranges from 0.4 to 2.4 microns and 6.2 to 15.5 microns, types of rocks, soils, and sediments can be identified. A radiometric channel in the 10 to 12 micron range will be used to obtain correlative data on surface temperature of the observables.

Synthetic Aperture Radar — Two synthetic aperture radars are proposed. The first, using a single frequency of 10 GHz, will operate in both wide coverage/low-resolution and narrow coverage/high-resolution modes. Applications are the mapping of ice fields (at night or through cloud cover), and determining sea surface winds and pollution patterns by variations in backscatter. Dual polarization will be used.

The second radar will utilize three frequencies at 3, 5.5, and 10 GHz, and dual polarization in each band. The primary application is determination of soil conditions and identification of crop types by comparison of the signals obtained in each of the frequency bands.

Passive Microwave Radiometer — By using five frequencies, covering the range from 5 to 37 GHz, with dual polarization in each band, this sensor will be used primarily to obtain meteorological data defining the areal extent and rate of precipitation, obtain a measure of sea surface roughness and therefore surface wind velocity, and will also measure the temperature of the sea surface. Observations can be obtained at night and through cloud cover.

Laser Altimeter/Scatterometer — The primary applications of this instrument are:

- a) Profiling of mountainous terrain

- b) Determination of wind and wave statistics on the ocean surface
- c) Determining the surface texture of snow and ice fields
- d) Profiling of the concentration of chlorophyll beneath the ocean surface.

Effort under SR&T funding will be required to determine the feasibility of the latter.

Imaging Spectrometers (Water Pollution) — Two instruments are proposed, both with the capability of obtaining imagery and spectral signatures of the water surface within the visual and near-visual range of the spectrum. One instrument will be of low resolution with a wide field of view in a strapped-down configuration, and the other will use telephoto optics and two-axis gimbaling for detailed examination of small areas.

The design concept is based upon the Multichannel Ocean Color Sensor (MOCS), developed by TRW Systems, and flight-proven in Convair 990 aircraft tests. Specific applications are identification of areas and types of water pollution, with additional capability of the identification of the concentration of chlorophyll in the ocean water.

Imaging IR Radiometers (Water Pollution) — Two instruments are also proposed, with low and high resolution, to obtain correlative data for the imaging spectrometers defined above. Thermal imagery will be obtained of the water surface temperature, defining thermal gradient patterns indicative of various types of pollution on the surface of the water.

Star Tracking Telescope — This sensor, originally proposed by the University of Michigan, will obtain a measure of the global distribution of the density of the atmosphere, a parameter required for numerical weather forecasting.

Air Pollution Sensors — The Visible Radiation Polarimeter will measure the degree and direction of the polarization of the upwelling radiation from the sunlit atmosphere. From these data the concentration, size, and distribution of particulate matter in the atmosphere can be determined. Of the air pollution sensors, this is the only instrument which can be used for measurement of pollution of the atmosphere by particulates.

The Ultraviolet Upper Atmospheric Sounder will measure the vertical profiles and changes in ozone and nitrous oxide, in the altitude ranges of 30 to 55 and 60 to 90 km, respectively.

The Advanced Limb Radiance Inversion Radiometer is also used for upper atmospheric research, measuring the vertical distribution of the following constituents from the upper troposphere to the mesosphere: NO_2 , H_2O , CH_4 , O_3 , HNO_3 , CO_2 , N_2O and sulfate aerosols. The more recent acronym for this experiment is LACATE, (Lower Atmosphere Composition and Temperature Experiment.)

The Carbon Monoxide Pollution Experiment, more recently identified by the acronym CIMATS (Correlation Interferometric Measurement of Atmospheric Trace Species), is a Michelson type correlation interferometer, and will be used for both mapping of the global distribution of atmospheric pollutants, and for measuring the vertical profiles using a limb radiance mode. Species which can be measured are CO , CO_2 , SO_2 , H_2O , NH_4 , NO , N_2O , and NO_2 .

The Air Pollution Correlation Spectrometer, sensitive in the wavelength range from 2800 to 5000 Angstroms, will be used to determine the global distribution of sulfur dioxide (from industrial discharge) and NO_2 (automobile exhaust pollution).

The High Speed Interferometer will obtain measurements of the total concentration and vertical distribution of the following atmospheric pollutants and constituents: CO , CO_2 , NO , HCl , O_3 , NO_2 , SO_2 , NH_3 , C_2H_2 , C_2H_4 , and H_2CO . The sensor is a Michelson-type interferometer.

The Remote Gas Filter Correlation Analyzer, currently under development for aircraft flight tests by Science Applications, Inc., under the AAPE program, is recommended to obtain global measurements, during day or night, of the concentration of the following atmospheric pollutants: CO , CO_2 , NO , NO_2 , NH_3 , and CH_4 . The instrument is sensitive to radiation over the spectral range from 2 to 20 microns.

IR Radiometers (Correlative Data-Air Pollution) — The TIROS-N Advanced Very-High Resolution Radiometer (AVHRR) is recommended to obtain correlative data for the air pollution sensors, primarily the Remote Gas Filter Correlation Analyzer. Data obtained will be high resolution imagery of cloud cover, and measurements of terrain and ocean temperature.

The TIROS-N Operational Vertical Sounder (TOVS) is also recommended as a correlative instrument, with the primary function being that of obtaining atmospheric temperature profiles. Additional data obtained will be vertical profiles of water vapor, and the total amount of ozone content in the atmosphere.

4.1.2 Sensor Utilization — Low-Cost Pollution Mission

For this mission, where only 16 of the above 29 instruments are used, the sensors and their utilization are summarized in Table 4-2.

TYPE	NO.	SENSOR	UTILIZATION
OPTICAL VIEWERS	32	WIDE ANGLE VIEWER	LARGE AREA VIEWING AND ORIENTATION
	1	TRACKING TELESCOPE	HIGH RESOLUTION VIEWING - SPECIFIC TARGETS
RF DCS	33	DATA COLLECTION SYSTEM	TO OBTAIN DATA FROM SURFACE PLATFORMS
FILM CAMERAS	2	POINTABLE IDENTIFICATION CAMERA 70 MM FILM	LARGE AREA TARGET IDENTIFICATION
	5	MULTISPECTRAL CAMERA SYSTEM 24 X 24 CM (9 X 9 IN.) FILM	MULTIBAND PHOTOGRAPHY - POLLUTANT IDENTIFICATION
	6	HIGH RESOLUTION MULTISPECTRAL CAMERA SYSTEM (70 MM FILM)	HIGH RESOLUTION MULTIBAND PHOTOGRAPHY - SPECIFIC TARGETS - POLLUTANT IDENTIFICATION
	7	MULTIRESOLUTION FRAMING CAMERA SYSTEM 24 X 24 CM (9 X 9 IN.) FILM	SIMULTANEOUS FALSE COLOR IR PHOTOGRAPHY WITH THREE STAGES OF RESOLUTION
MULTISPECTRAL IMAGING LINE SCANNER	8	HIGH RESOLUTION WIDEBAND MULTISPECTRAL SCANNER (20 SPECTRAL BANDS)	MULTIBAND IMAGERY VISUAL, MID-IR, THERMAL IR RANGES AGRICULTURE, FORESTRY, GEOLOGICAL APPLICATIONS
IMAGING SPECTROMETER (WATER POLLUTION)	13	VISIBLE IMAGING SPECTROMETER	WATER POLLUTION - IDENTIFICATION AND PATTERNS (WIDE AREA - LOW RESOLUTION)
IMAGING RADIOMETER (WATER POLLUTION)	14	IR MULTISPECTRAL MECHANICAL SCANNER	WATER POLLUTION - THERMAL PATTERNS (WIDE AREA - LOW RESOLUTION)
AIR POLLUTION SENSORS	20	VISIBLE RADIATION POLARIMETER	AIR POLLUTION (PARTICULATE) - TYPE AND DISTRIBUTION
	26	ADVANCED LIMB RADIANCE INVERSION RADIOMETER	DISTRIBUTION OF TEMPERATURE, OZONE, H ₂ O, NO _x , AND SULFATE AEROSOLS (TROPOSPHERE TO MESOSPHERE)
	23	CARBON MONOXIDE POLLUTION EXPERIMENT	AIR POLLUTION (GASEOUS) - GLOBAL AND VERTICAL DISTRIBUTION - NO _x , CO _x , SO _x , NH ₄
	21	AIR POLLUTION CORRELATION SPECTROMETER	AIR POLLUTION (GASEOUS) - GLOBAL DISTRIBUTION SO ₂ AND NO ₂
	22	HIGH SPEED INTERFEROMETER	AIR POLLUTION (GASEOUS) - GLOBAL AND VERTICAL DISTRIBUTION - NO _x , CO _x , SO _x , NH ₃
	25	REMOTE GAS FILTER CORRELATION ANALYZER	AIR POLLUTION (GASEOUS) - GLOBAL DISTRIBUTION NO _x , CO _x , SO _x , NH ₃

Table 4-2. Sensor Utilization - Low-Cost Mission

4.2 DEVELOPMENTAL STATUS OF SENSORS

The developmental status of the sensors which have been identified as candidates for the Baseline and Low-Cost Pollution missions is summarized in Tables 4-3 and 4-4. Of the 29 sensors, two have been proven in space flight, 14 have been partially developed, primarily under the Advanced Applications Flight Experiment (AAFE) program, and development of the balance of 13 remains to be initiated.

Optical Viewers — Considering the sensors by type, the first group is that of optical viewers, used for visual sightings by the crew from within the Sortie Laboratory. The Wide Angle Viewer design concept is based upon that of a similar instrument, the WILD NF2 Navigation Sight which is used with the Wild-Heerbrugg RC-10 metric camera, currently in production for use in aircraft. Modifications in the optical fields of view are required, in addition to the incorporation of a hydrogen-alpha line filter for observation of lightning flashes associated with sferics (thunderstorm activity). In addition, incorporation of a closed-circuit television camera at the eyepiece is recommended for real-time display of imagery of the terrain on a CRT display within the Sortie Laboratory.

Critical components of the Tracking Telescope have been developed by the Itek Corporation, under subcontract from the General Electric Company. Work remaining consists of the development of a space-qualified prototype.

RF Data Collection System — An RF data collection system has been developed by Radiation Inc., Melbourne, Florida, for use in the ERTS-A satellite and, in addition, a similar system has been configured for use in the TIROS-N program. No additional development will be required for the Manned Earth Observatory application.

Film Cameras — Considering the two camera systems using 70 mm film, both the Pointable Identification Camera (two cameras) and the High Resolution Multispectral Camera System (six cameras) require the use of two-axis gimbals for pointing at selected targets, and in the latter case the use of telephoto (long focal-length) optics is required. Development of both instruments is required, although similarity to the Skylab S-190 Multispectral Photographic Facility (developed by the Itek Corporation) may enable reduction of development costs.

The Panoramic Camera, developed by the Itek Corporation, has been flown in the Apollo 15, 16, and 17 program in which high resolution stereo photography was obtained from the lunar surface, and used for the development of topographic maps. No additional development is required.

The Wide-Angle Framing Camera, using 9 x 18 inch film, has been partially developed by the Itek Corporation.

Table 4-3. Developmental Status - Experiment Sensors (1 of 2)

NO.	TYPE	SENSOR	NEW DEVELOPMENT	PARTIALLY DEVELOPED	SPACE FLIGHT PROVEN
12	LASER	LASER ALTIMETER/SCATTEROMETER	TRW CONCEPT		
13	IMAGING SPECTROMETERS (WATER POLLUTION)	VISIBLE IMAGING SPECTROMETER		TRW (AAFE)	
15		HIGH RESOLUTION VISIBLE IMAGING SPECTROMETER		TRW (AAFE)	
14	IMAGING IR RADIOMETERS (WATER POLLUTION)	IR MULTISPECTRAL MECHANICAL SCANNER	TRW CONCEPT		
16		HIGH RESOLUTION IR MULTISPECTRAL SCANNER	TRW CONCEPT		
18	STAR TRACKER	STAR TRACKING TELESCOPE	UNIV MICH CONCEPT		
20	AIR POLLUTION SENSORS	VISIBLE RADIATION POLARIMETER		TRW (IR&D) UCLA (AAFE)	
19		UV UPPER ATMOSPHERE SOUNDER		UNIV OF COLO (AAFE)	
26		ADVANCED LIMB RADIANCE INVERSION RADIOMETER		NCAR (AAFE)	
23		CARBON MONOXIDE POLLUTION EXPERIMENT		GE (AAFE & IR&D)	
21		AIR POLLUTION CORRELATION SPECTROMETER		BARRINGER RESEARCH	
22		HIGH SPEED INTERFEROMETER		JPL (AAFE & OMSF)	
25		REMOTE GAS FILTER CORRELATION ANALYZER		SCIENCE APPLIC (AAFE)	
27	IR RADIOMETERS (CORRELATIVE DATA - AIR POLLUTION)	TIROS-N ADVANCED VERY HIGH RESOLUTION RADIOMETER		ITT (CONTRACT INITIATED)	
28		TIROS-N OPERATIONAL VERTICAL SOUNDER	UNDER STUDY (NOAA)		

Table 4-4. Developmental Status - Experiment Sensors (2 of 2)

NO.	TYPE	SENSOR	NEW DEVELOPMENT	PARTIALLY DEVELOPED	SPACE FLIGHT PROVEN
32	OPTICAL VIEWERS	WIDE ANGLE VIEWER	SIMILAR TO WILD NF2 NAVIGATION SIGHT		
1		TRACKING TELESCOPE		ITEK CORP	
33	RF DCS	DATA COLLECTION SYSTEM			ERTS-A
2	FILM CAMERAS	POINTABLE IDENTIFICATION CAMERA 70 MM FILM	SIMILAR TO SKYLAB S-190 (2 CAMERAS)		
3		PANORAMIC CAMERA (5 IN. FILM)			APOLLO 15-17 (ITEK)
4		WIDE ANGLE FRAMING CAMERA 24 x 48 CM. (9 x 18 IN.) FILM		ITEK CORP	
5		MULTISPECTRAL CAMERA SYSTEM 24 x 24 CM (9 x 9 IN.) FILM	TRW CONCEPT		
6		HIGH RESOLUTION MULTISPECTRAL CAMERA SYSTEM (70 MM FILM)	SIMILAR TO SKYLAB S-190		
7		MULTIRESOLUTION FRAMING CAMERA SYSTEM 24 x 24 CM (9 x 9 IN.) FILM	TRW CONCEPT		
8	MULTISPECTRAL IMAGING LINE SCANNER	HIGH RESOLUTION WIDEBAND MULTISPECTRAL SCANNER (20 SPECTRAL BANDS)		SIMILAR TO SKYLAB S-192	
9	IR SPECTROMETER	LWIR SPECTROMETER (6.2 - 15.5 μ , 0.4 - 2.4 μ)		SIMILAR TO SKYLAB S-191	
10	SYNTHETIC APERTURE RADARS	WIDEBAND SYNTHETIC APERTURE RADAR	STUDIES IN PROGRESS AT JPL		
11		MULTIFREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR	STUDIES IN PROGRESS AT JPL		
29	PASSIVE MICROWAVE	PASSIVE MICROWAVE RADIOMETER (PMMR) (5 BANDS, 4.99 - 37 GHz)	STUDIES IN PROGRESS AT NASA-GSFC		

Both the Multispectral Camera System and the Multiresolution Framing Camera System, using 9 x 9 inch film, are concepts proposed by TRW Systems, and development is required.

Multispectral Imaging Line Scanner — The design concept of the High Resolution Wideband Multispectral Scanner is based upon the design of the Skylab S-192 Multispectral Scanner, which has been developed by the Honeywell Radiation Center. Recommended modifications include the addition of gimbaling for off-nadir pointing and an increase in the number of spectral bands from 13 to 20.

IR Spectrometer — This instrument is similar to the Skylab S-191 Infrared Spectrometer, which has been developed by the Martin Marietta Corporation and Block Engineering. Only a minor modification is recommended, the addition of one radiometric channel.

Synthetic Aperture Radars — For both of the synthetic aperture radars, complete development is required. Preliminary design studies of various SAR configurations have been conducted at the Jet Propulsion Laboratory under contract from the NASA Manned Spacecraft Center. However, hardware development for the Space Shuttle application has not been initiated.

Passive Microwave — The candidate sensor is based upon the 5-channel Passive Multichannel Microwave Radiometer (PMMR) design configuration developed by the NASA Goddard Space Flight Center for the Earth Observatory Satellite program. The initial configuration was based upon the use of electronically-scanned phased arrays. However, mechanically-scanned parabolic antennas are being considered as a means for reducing developmental costs. Studies are also being conducted at the Jet Propulsion Laboratory of the latter configuration. These activities have not proceeded beyond the study phase, and hardware development remains to be initiated.

Laser Altimeter/Scatterometer — The configuration of this instrument is based upon a design concept developed by TRW Systems. The intended application is twofold: profiling of mountainous areas and the sea surface, and profiling of the depth of plankton in ocean water. SR&T effort is required to prove the feasibility of the latter application, and development of hardware has not been initiated.

Imaging Spectrometers (Water Pollution) — An instrument of this type, the Multichannel Ocean Color Sensor (MOCS) has been developed by TRW and has been flown in Convair 990 flight tests under the AAFFE program. For the MEO application, development of flight hardware is feasible, but additional effort is required to develop techniques of data analysis and interpretation.

The High Resolution Visible Imaging Spectrometer differs in configuration from the Visible Imaging Spectrometer only by the addition of gimbals and the use of telephoto (long focal-length) optics.

Imaging IR Radiometers (Water Pollution) — Both of the proposed instruments are based upon design concepts proposed by TRW Systems. Using the same wavelength regions as the EOS Sea Surface Temperature Imaging Radiometer under study by the NASA Goddard Space Flight Center, the proposed IR Multispectral Mechanical Scanner would use a conical scan pattern in order to eliminate the variation in radiance from the sea surface which results from the use of wide-angle cross-track line scanning.

However, the proposed High Resolution IR Mechanical Scanner, using a two-axis gimbal system and telephoto optics, would have a raster scan, suitable for use with a small optical field of view.

Development of both types of instruments is required.

Star Tracker — Based upon a University of Michigan concept, an instrument of this type was initially proposed for the Apollo Applications A program. Using an inertially-stabilized star tracker, the design is based upon the use of state-of-the-art components. However, development of hardware is required.

Air Pollution Sensors — All of the seven proposed sensors have been partially developed, primarily under the AAFFE program. However, in all cases additional work is required to demonstrate the feasibility of obtaining the desired measurements of atmospheric constituents or pollutants from orbit by demonstration in aircraft, balloon, or Small Applications Technology Satellite test vehicles.

IR Radiometers — A contract has recently been initiated at ITT for development of the Tiros-N Advanced Very High Resolution Radiometer (AVHRR). Development of flight hardware will be completed well in advance of the date required for use in the Manned Earth Observatory.

The Tiros-N Operational Vertical Sounder (TOVS) design configuration is currently under study by NOAA, and development of hardware has not been initiated.

4.3 ALTERNATE SENSORS

The complement of candidate sensors for the Baseline and Low-Cost missions was reviewed and possible alternates were identified in an effort to determine if the developmental lead time and costs of the two sensor payloads could be reduced.

A summary of the alternate instruments which were identified is presented in Tables 4-5 and 4-6. In general, few alternates were found to be available which would fulfill the objectives of the experiments of the two missions.

The Pointable Identification Camera (Sensor No. 2) consists of two 70 mm film cameras, using panchromatic and color film, in a two-gimballed configuration. A possible alternate is the Skylab S-190 Multispectral Photographic Facility. However, the latter has a complement of six 70 mm film cameras in a fixed mount, which would not permit off-nadir pointing.

The High Resolution Multispectral Camera System (Sensor No. 6) has a complement of six 70 mm film cameras in a two-axis gimbal system, and uses telephoto (long focal-length) lenses. The Skylab S-190 Multispectral Photographic Facility would be a suitable substitute, with a change in the optics from wide-angle to telephoto and with the addition of a two-gimbal mount.

The High Resolution Wideband Multispectral Scanner (Sensor No. 8) is similar to the Skylab S-192 Multispectral Scanner, but uses a single-axis gimbal for cross-track pointing and has 20 spectral bands rather than 13. With these two modifications, the S-192 instrument would be suitable.

An alternate for the LWIR Spectrometer (Sensor No. 9) is the Skylab S-191 Infrared Spectrometer. However, it is recommended that a radiometric channel be added, in the 10.1 to 12.5 micron spectral range.

For the Passive Microwave Radiometer (Sensor No. 29) no single alternate sensor is available which will fulfill the requirement for the use of five wavelength bands within the range of 5 to 37 GHz. This sensor is currently being considered by the NASA Goddard Space Flight Center

Table 4-5. MEO Sensor Payload and Alternate Sensors (1 of 2)

NO.	SENSOR	ALTERNATE SENSOR	COMMENTS
32	WIDE ANGLE VIEWER	NONE	-
1	TRACKING TELESCOPE	NONE	-
33	DATA COLLECTION SYSTEM	NONE	-
2	POINTABLE IDENTIFICATION CAMERA 70MM FILM	SKYLAB S-190 MULTISPECTRAL PHOTOGRAPHIC FACILITY (WITH 2-AXIS GIMBALS ADDED)	POINTABLE IDENTIFICATION CAMERA USES TWO CAMERAS. S-190 HAS SIX CAMERAS ON COMMON MOUNT
3	PANORAMIC CAMERA (5 IN. FILM)	NONE	-
4	WIDE ANGLE FRAMING CAMERA 24 x 48 CM (9 x 18 IN.) FILM	NONE	-
5	MULTISPECTRAL CAMERA SYSTEM 24 x 24 CM (9 x 9 IN.) FILM	NONE	-
6	HIGH RESOLUTION MULTISPECTRAL CAMERA SYSTEM (70 MM FILM)	SKYLAB S-190 MULTISPECTRAL PHOTOGRAPHIC FACILITY (WITH 2-AXIS GIMBAL ADDED)	IF S-190 USED, MUST CHANGE OPTICS FROM WIDE ANGLE TO TELEPHOTO
7	MULTIRESOLUTION FRAMING CAMERA SYSTEM 24 x 24 CM (9 x 9 IN.) FILM	NONE	-
8	HIGH RESOLUTION WIDEBAND MULTI- SPECTRAL SCANNER (20 SPECTRAL BANDS)	SKYLAB S-192 MULTISPECTRAL SCANNER WITH 1-AXIS GIMBAL ADDED	S-192 HAS ONLY 13 SPECTRAL BANDS. P.I. DESIRES 20 SPECTRAL BANDS.
9	LWIR SPECTROMETER (6.2 - 15.5 μ , 0.4 - 2.4 μ)	SKYLAB S - 191 INFRARED SPECTROMETER	-
10	WIDEBAND SYNTHETIC APERTURE RADAR	NONE	NO SAR HARDWARE DEVELOPED BY NASA TO DATE FOR SPACE FLIGHT
11	MULTIFREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR	NONE	SAME AS ABOVE
29	PASSIVE MICROWAVE RADIOMETER (PMMR) (5 BANDS, 4.99 - 37 GHz)	NIMBUS E (19.35 GHz) - AEROJET CORP NIMBUS F (37.5 GHz) - AEROJET CORP NIMBUS E MICROWAVE SOUNDER (JPL) (5 BANDS, 22-59 GHz) NIMBUS F SCANNING MICROWAVE SOUNDER (JPL) (5 BANDS, 22-55 GHz)	USE OF ALTERNATE SENSORS WILL NOT SATISFY SCIENTIFIC OBJECTIVES OF PMMR DUE TO USE OF FEWER OR DIFFERENT FREQUENCY BANDS

Table 4-6. MEO Sensor Payload and Alternate Sensors (2 of 2)

NO.	SENSOR	ALTERNATE SENSOR	COMMENTS
12	LASER ALTIMETER/SCATTEROMETER	NASA-MSFC LED-PUMPED Nd:YAG LASER (AAFE 1971) IS A POSSIBILITY	--
13	VISIBLE IMAGING SPECTROMETER	OCEANIC SCANNING SPECTROPHOTOMETER FOR EOS (WARREN HOVIS, NASA-GSFC)	EOS OSS IS IN R&D STAGE
15	HIGH RESOLUTION VISIBLE IMAGING SPECTROMETER	OCEANIC SCANNING SPECTROPHOTOMETER FOR EOS (WARREN HOVIS, NASA-GSFC) WITH TELEPHOTO LENS	EOS OSS IS IN R&D STAGE
14	IR MULTISPECTRAL MECHANICAL SCANNER	EOS SEA SURFACE TEMPERATURE IMAGING RADIOMETER	EOS SSTIR IS IN STUDY PHASE
16	HIGH RESOLUTION IR MULTISPECTRAL SCANNER	EOS SEA SURFACE TEMPERATURE IMAGING RADIOMETER MODIFIED FOR NARROW FOV (TELEPHOTO OPTICS, POINTABLE)	USE OF EOS SSTIR WILL REQUIRE MAJOR REDESIGN FOR NARROW FOV
18	STAR TRACKING TELESCOPE	NONE	-
20	VISIBLE RADIATION POLARIMETER	NONE	-
19	UV UPPER ATMOSPHERE SOUNDER	NONE	-
26	ADVANCED LIMB RADIANCE INVERSION RADIOMETER	NONE	-
23	CARBON MONOXIDE POLLUTION EXPERIMENT	NONE	-
21	AIR POLLUTION CORRELATION SPECTROMETER	NONE	-
22	HIGH SPEED INTERFEROMETER	NONE	-
25	REMOTE GAS FILTER CORRELATION ANALYZER	NONE	-
27	TIROS-N ADVANCED VERY HIGH RESOLUTION RADIOMETER	NONE	-
28	TIROS-N OPERATIONAL VERTICAL SOUNDER	NONE	-

for use on the Earth Observatory Satellite. Two single-channel instruments using electronically-phased arrays have been developed for Nimbus E and F by the Aerojet General Corporation, and two multichannel instruments using parabolic antennas have been developed by the Jet Propulsion Laboratories for the same programs. Due to the use of higher frequency bands, the alternate sensors will be adversely affected by precipitation within the atmosphere and are not recommended.

For the Laser Altimeter/Scatterometer (Sensor No. 12), the Nd:YAG LED-pumped laser sponsored under the AAFE program during FY 1971 is a possibility. The latter instrument would fulfill the function of altimetry, but the effort has not been directed toward the function of scatterometry. With the deletion of the latter requirement, the alternate can be considered.

An alternate for Sensors 13 and 15, the Visible Imaging Spectrometer and the High Resolution Visible Imaging Spectrometer, the Oceanic Scanning Spectrophotometer, currently in experimental form at the NASA Goddard Space Flight Center, can be considered. To fulfill the high resolution requirement of Sensor No. 15, the use of telephoto (long focal-length) optics and a two-axis gimbal system would be required.

The Sea Surface Temperature Imaging Radiometer, currently in the study phase at the NASA Goddard Space Flight Center can be considered as a possible alternate for sensors 14 and 16. To fulfill the function of the latter, the use of telephoto (long focal-length) and two-axis gimballing would be required.

For the remainder of the sensors specified for the two missions of the Manned Earth Observatory, no suitable alternates were identified.

5.0 EARLY FACILITY SENSOR ACCOMMODATIONS

Two configurations of the early Manned Earth Observatory facility have been developed using the Sortie Laboratory and pallet and two complements of sensors previously identified for the Baseline and Low-Cost Pollution missions.

In both cases the sensor payload consists of a relatively large number of instruments, 29 for the Baseline mission and 16 for the Low-Cost mission, making maximum use of the Shuttle payload capability. This large payload capability enables numerous observations to be made simultaneously in support of the mission experiments to be conducted.

An additional consideration was that of target availability during the relatively short duration of the early Sortie Lab mission. In order to maximize the amount of data which would be obtained during the relatively short mission with only five days of operation in orbit, provision has been made in the design of most of the sensors for off-nadir pointing capability, permitting the observation of target areas which otherwise could not be observed if the sensors were used in a strapped-down configuration with the lines of sight directed toward the nadir.

This capability is illustrated in Figure 5-1, assuming an orbit which would pass over the Central Valley of California. Simultaneous sightings can be obtained from the coastal area of San Francisco to the Lake Tahoe area, a distance of 220 Km (120 n. mi.) from an orbital altitude of 370 Km (200 n. mi.), requiring a cross-track pointing capability of only ± 31 degrees from the orbital plane. In addition, the air pollution sensors which require pointing to the limb of the earth can obtain simultaneous data on upper atmospheric air pollution.

The increase in target availability obtained by the use of gimballed sensors for the sensor payload of the low-cost mission is illustrated in Figure 5-2.

In order to obtain data simultaneously from a large number of target areas during the relatively short portion that each orbit is over continental land masses, rapid pointing of the sensors in sequence will be required. In order not to burden the crew with this requirement, the use of computer-controlled pointing is recommended, with the timeline

THE USE OF SENSORS WITH A LARGE RANGE OF POINTING ANGLES WILL
GREATLY INCREASE THE AMOUNT OF DATA OBTAINED DURING THE 7-DAY MISSION

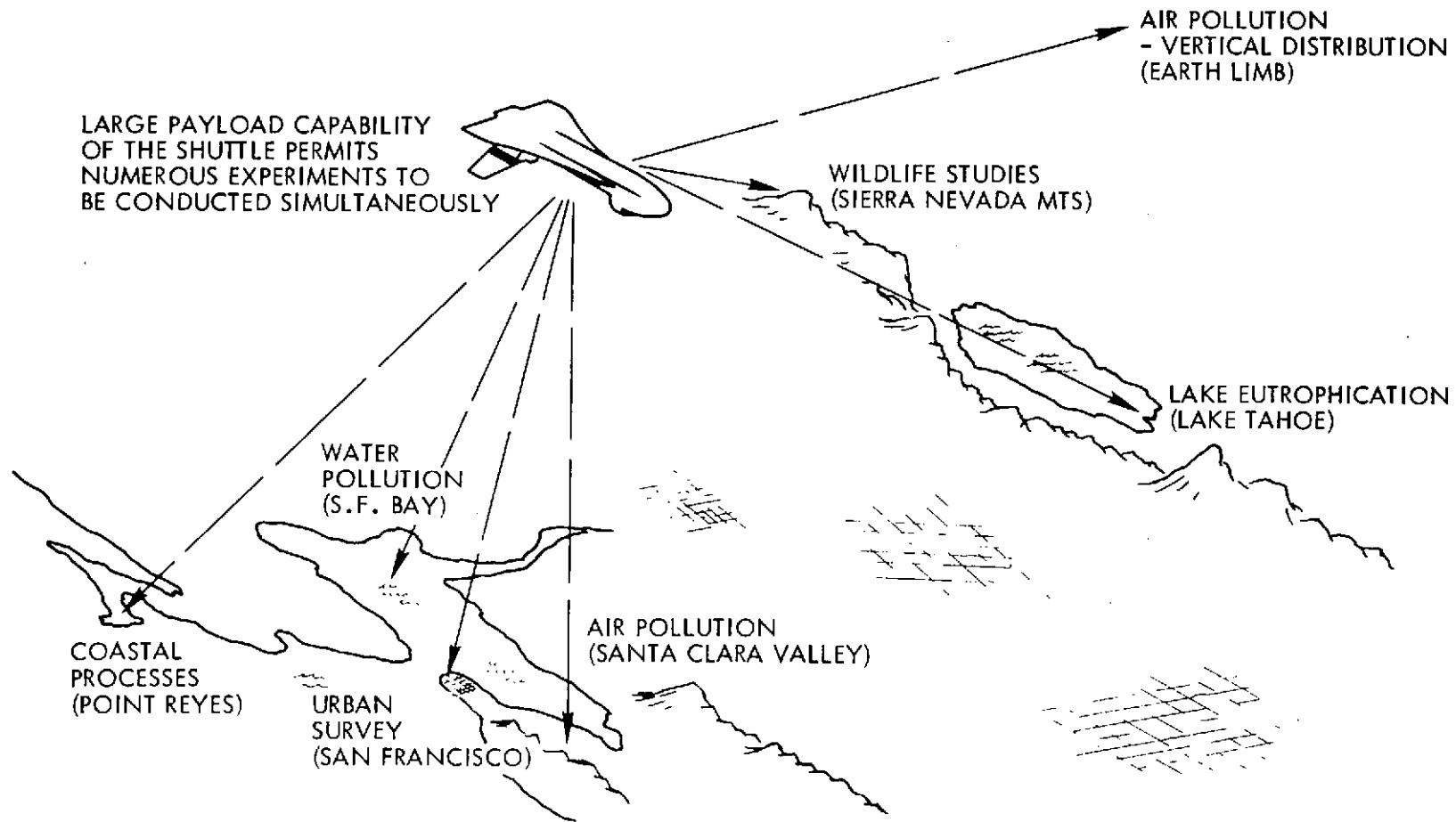


Figure 5-1. Off-Nadir Pointing Capability

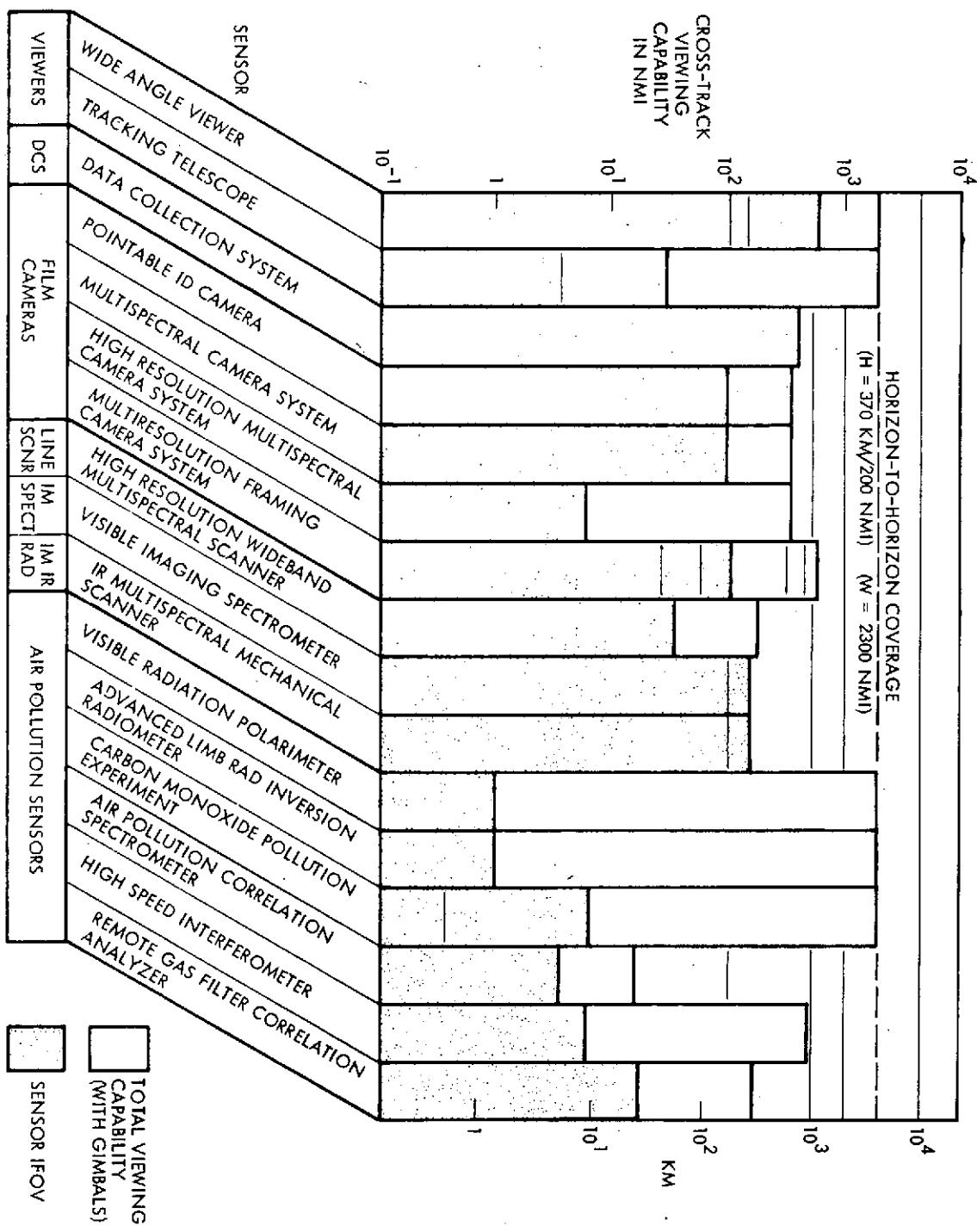


Figure 5-2. Increase in Cross-Track Ground Coverage by Use of Gimbaled Sensors

of pointing angles for all of the sensors being prepared prior to the mission. However, crew-controlled override or shut-down capability would be provided, based upon, i. e., visual observations with either the Wide-Angle Viewer or the Tracking Telescope. In case it is desired to obtain data using specific sensors from targets of opportunity, provision will be made for slaving selected sensors to the Tracking Telescope.

5.1 SENSOR ACCOMMODATIONS - BASELINE POLLUTION MISSION

The facility configuration which has been developed for the Baseline Pollution mission is illustrated in Figures 5-3 and 5-4. In order to obtain an unobstructed view of the earth, the majority of the sensors are mounted on the structure of the pallet and are separated by distances sufficiently large that each has an unobstructed field of view. The normal attitude of the Orbiter during the periods of earth observation would be inverted, with the local vertical being normal to the plane of the pallet structure.

The two optical viewers, the Tracking Telescope and Wide Angle Viewer, are located within the pressurized module of the Sortie Lab to permit real-time visual sightings by the crew. The Long Wavelength Infrared Spectrometer, requiring manually-controlled pointing, is also located in this area. The instruments have been mounted in the removable hatches and thus modification to preserve the structural integrity of the module is not required.

The RF data collection system antennas are mounted on the structure of the module, and the receiver, tape recorder, multiplexer, and S-band transmitter are located within the module.

The star-tracking instrument which is used in the Stellar Occultation experiment is deployed from the structure of the pressurized module, with a clear field of view looking aft toward the horizon, to permit tracking of stars into the atmosphere at the limb of the earth.

The remainder of the sensor payload is mounted on the pallet, with the exception of the synthetic aperture radar antennas, which are mounted on the structure of the Orbiter or on the Orbiter bay door. A major consideration in the development of this design has been to maintain unobstructed fields of views for the sensors. Thus, the camera systems and scanners, which either point away from the local vertical

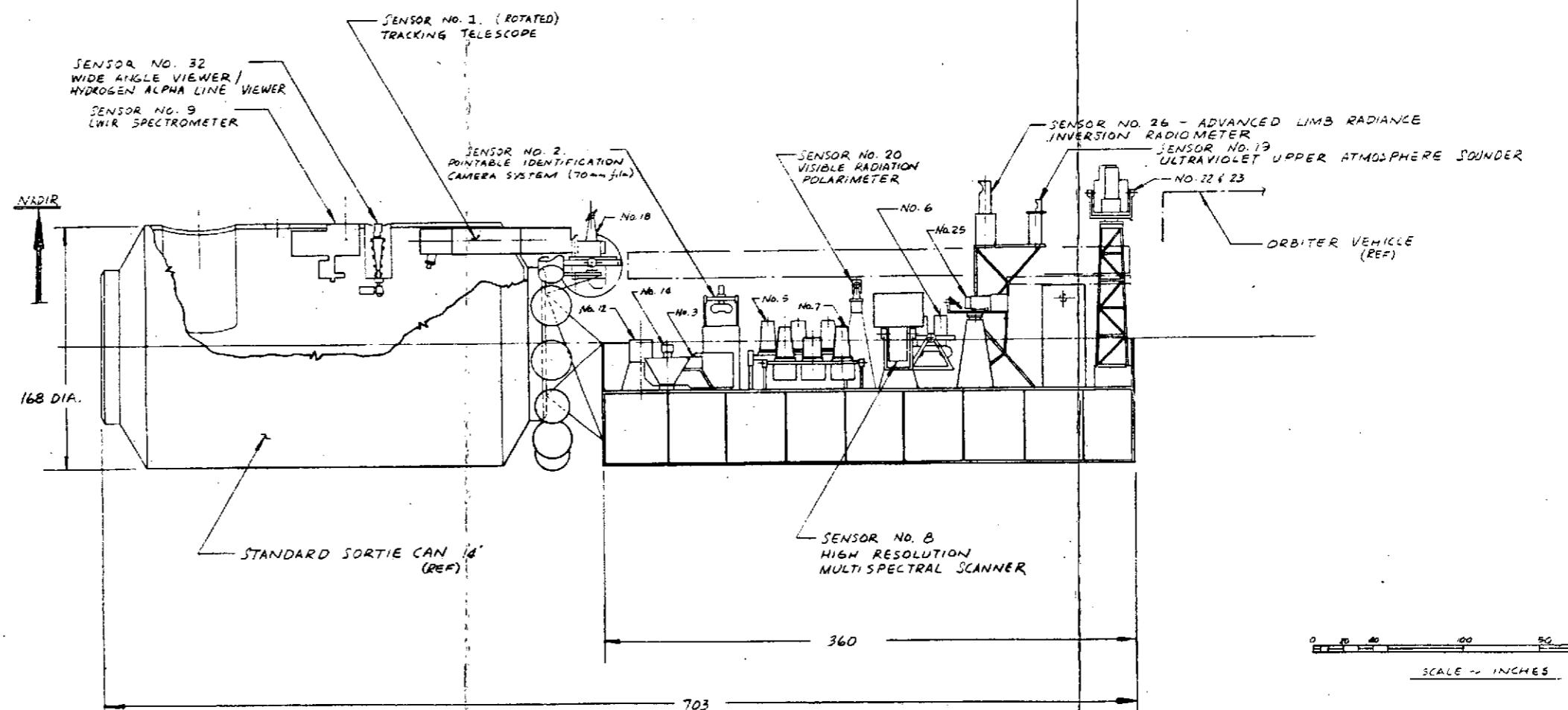


Figure 5-3. Facility Configuration - Baseline Pollution Mission (Elevation View)

Facility Configuration
Baseline Pollution Mission
(Elevation View)

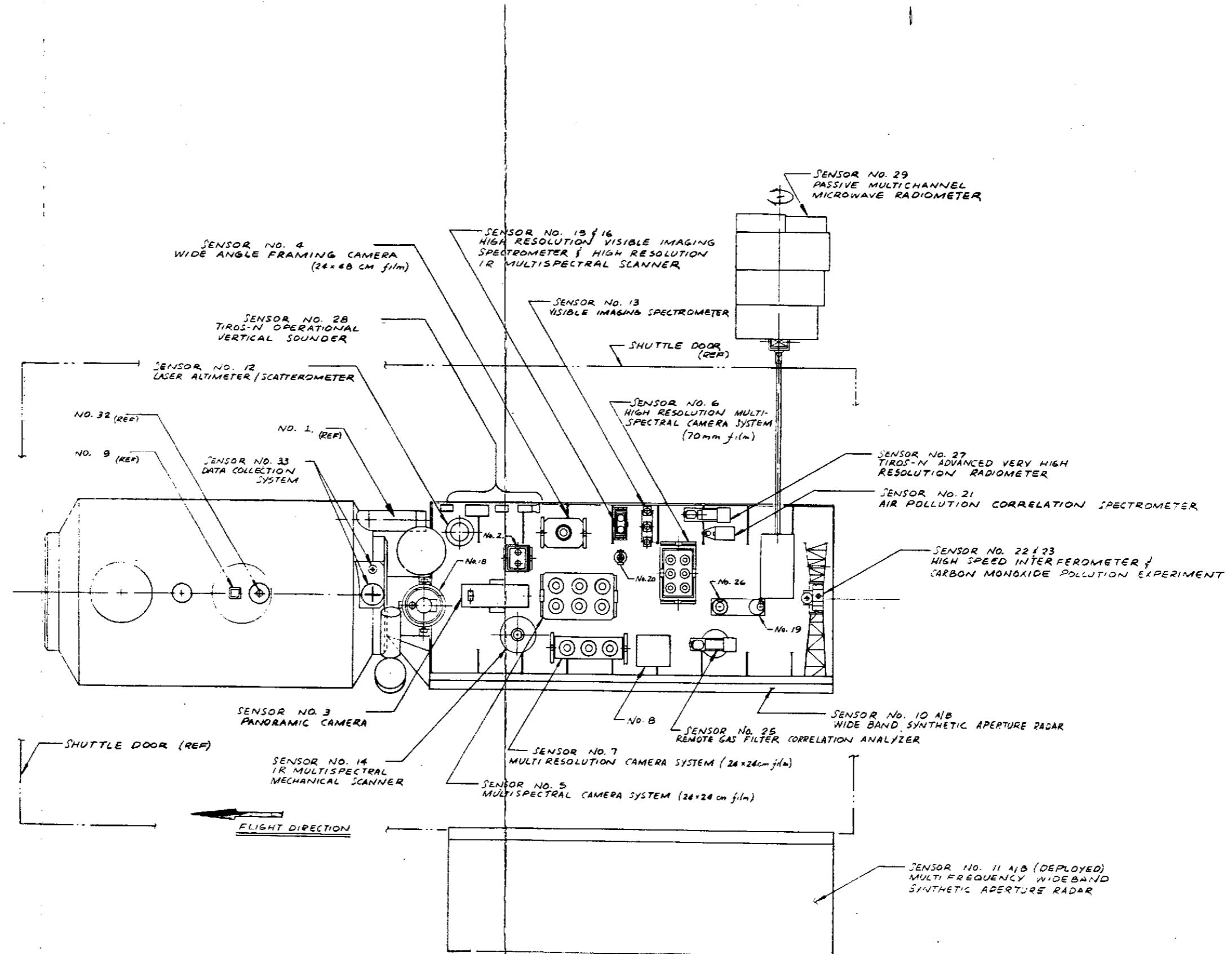


Figure 5-4. Facility Configuration — Baseline Pollution Mission (Plan View)

or scan about the nadir, are mounted directly on the bed of the pallet. As a number of these instruments are large and heavy (particularly the camera systems) mounting directly to the pallet structure is desirable to maintain structural integrity during launch and re-entry of the vehicle.

The lighter and smaller air pollution sensors, some of which require viewing the earth's limb, are mounted on elevated structures, with their deployment being controlled by the crew. The elevated location of these instruments permits sightings to the horizon, in most cases with full azimuthal freedom.

To prevent obstruction of the optical instruments, the antenna of the Passive Multichannel Microwave Radiometer will be deployed on an extendable boom, and then rotated about the pitch axis to achieve a vertical orientation of the antenna arrays. For the same reason, the antennas of the two synthetic aperture radars are mounted either on the Orbiter structure, alongside the pallet, or on the door of the Orbiter enclosing the payload bay.

A summary of the angular fields of view, and the ranges of the pointing angles of the sensors, is contained in Appendix A of this volume.

After development of this design in the study, consideration was given to the attitude and pointing control requirements of the sensors, and it was determined that an inertially stabilized star tracker would be required in order to provide an attitude reference frame for stabilization and pointing of the sensors. Although not included in this layout, the star tracking instrument could be mounted on the same elevated structure as the High Speed Interferometer and the Carbon Monoxide Pollution Experiment, at the rear of the pallet, with alignment of the star tracking instrument with respect to the pallet being monitored by optical auto-collimation.

5.2 SENSOR ACCOMMODATIONS -- LOW-COST POLLUTION MISSION

The facility configuration for the Low-Cost Pollution mission is illustrated in Figures 5-5, 5-6, and 5-7. In comparison to the Baseline mission, by the elimination of one low-priority experiment and sensors

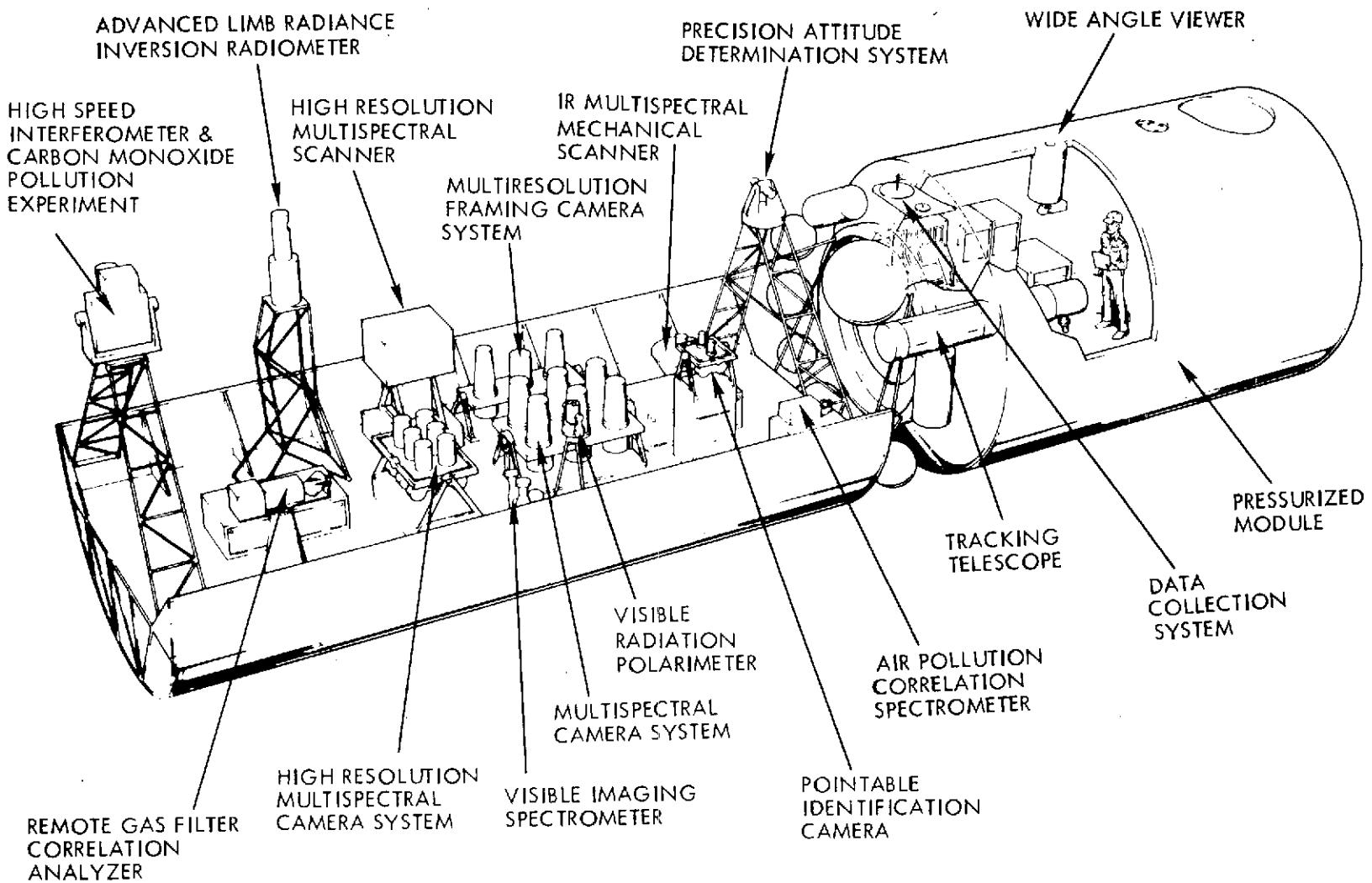


Figure 5-5. MEO Payload – Low Cost Pollution Mission

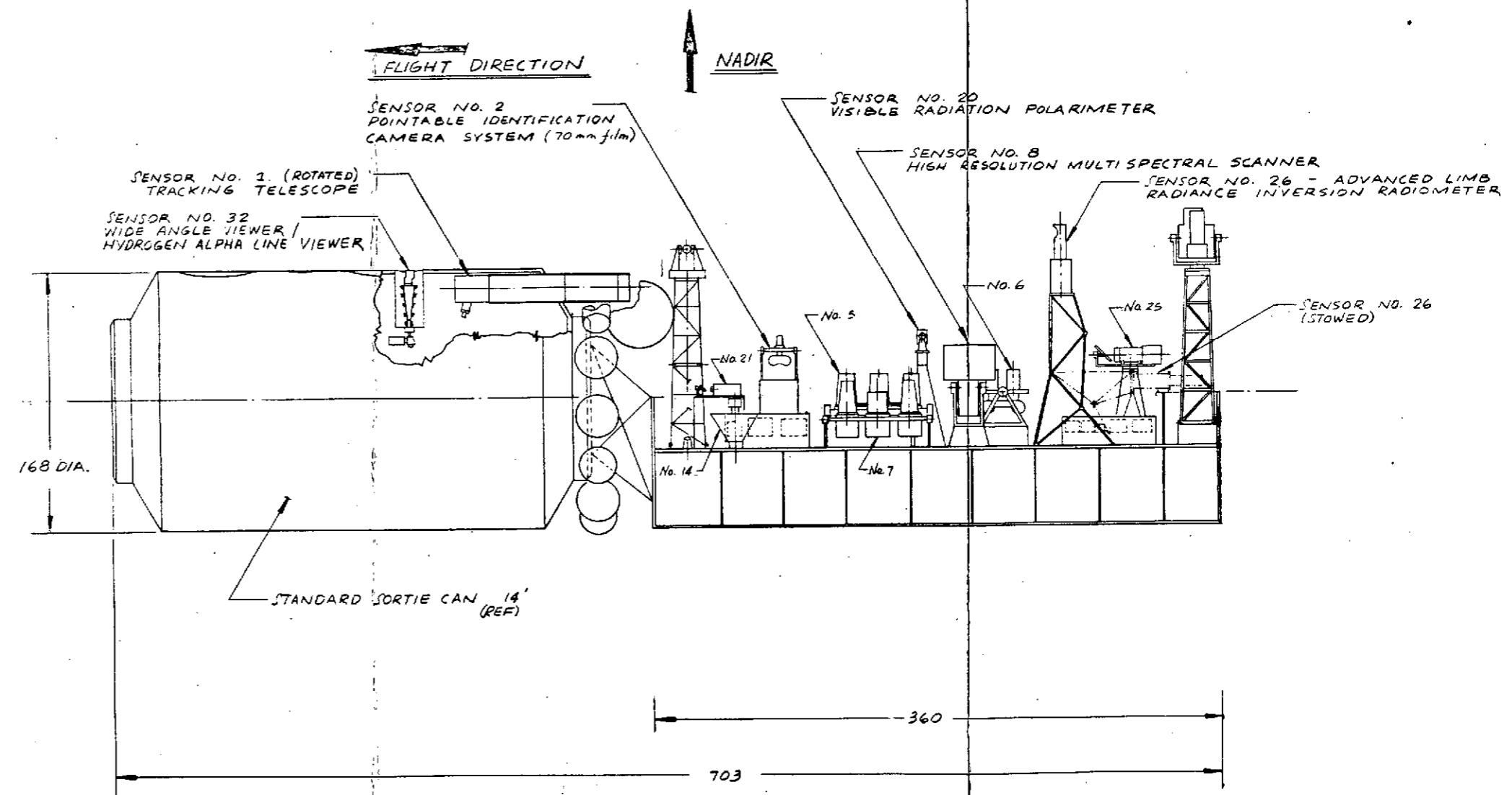


Figure 5-6. Facility Configuration
Low-Cost Pollution Mission
(Elevation View)

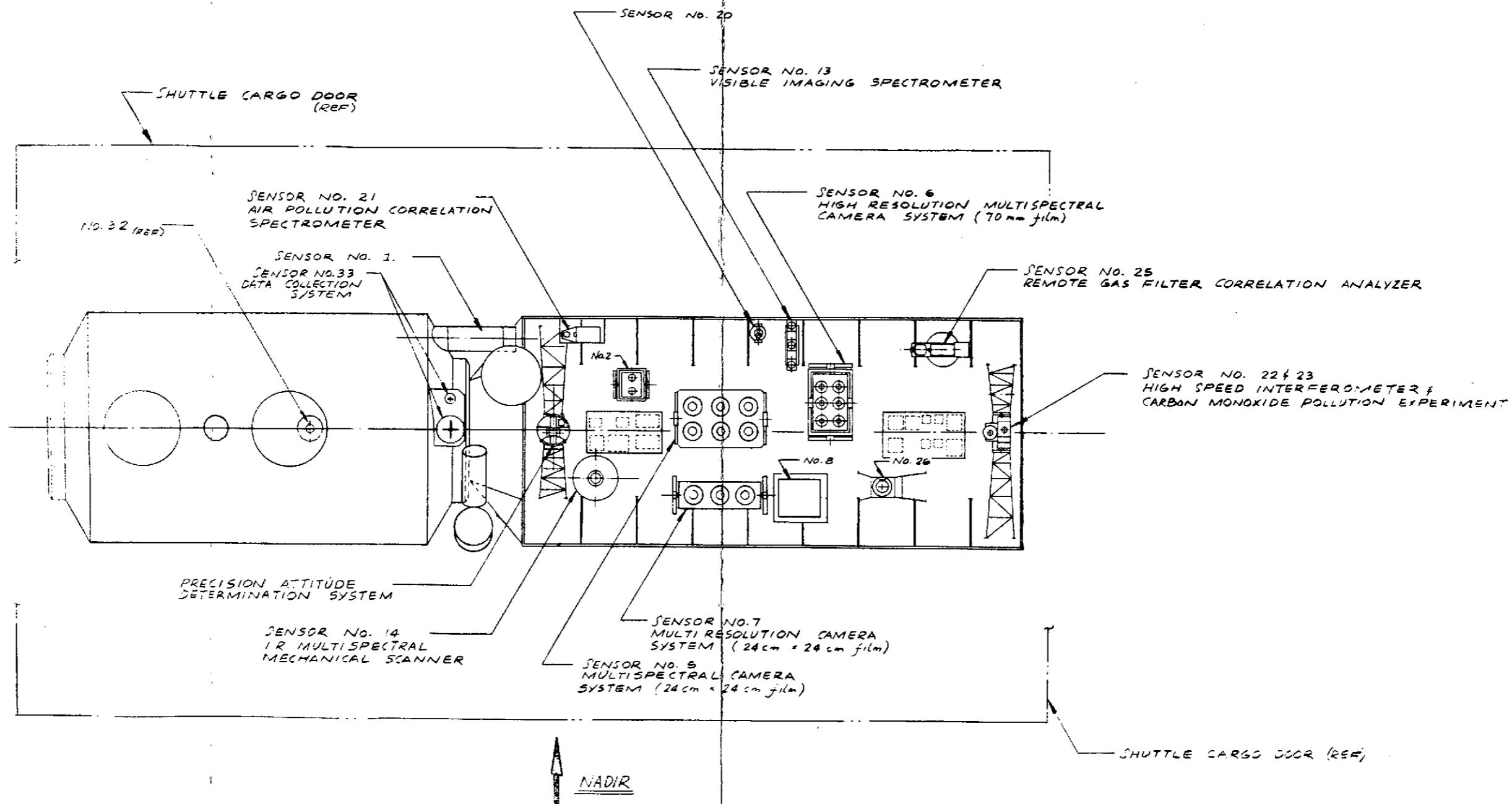


Figure 5-7. Facility Configuration
Low-Cost Pollution Mission
(Plan View)

obtaining only secondary or correlative data, the number of instruments has been reduced from 29 to 16. The LWIR Spectrometer, operated by the crew from within the pressurized module, has been deleted. From the pallet, the Panoramic and Wide Angle Framing cameras have been removed. The mission does not require the use of passive microwave nor synthetic aperture radar, and the Laser Altimeter/Scatterometer and high resolution water pollution sensors are eliminated. In addition, the Stellar Occultation experiment sensor is deleted, as well as the UV Upper Atmospheric Sounder and the two IR radiometers which obtained correlative data for the air pollution sensors.

Remaining are the sensors considered to be of primary importance-- the two optical viewers, operated by the crew from the pressurized module, four film camera systems, the 20-band Multispectral Scanner, the wide-angle low-resolution water pollution sensors, the six instruments required for the measurement of gaseous and particulate air pollution, and the data collection system. In the following section, the requirements of these sensors upon the spacecraft will be summarized.

Note that a Precision Attitude Determination System has been included in this payload, used for stabilization and pointing of the gimballed sensors. These requirements are discussed in detail in a following section.

5.2.1 Summary of Sensor Characteristics Affecting Facility Design

The primary characteristics of the sensor payload affecting the design of the early Manned Earth Observatory facility are weight, power, and data recording requirements. These are summarized in Figures 5-8, 5-9, and 5-10. Referring to the first Figure, the heaviest of the instruments is the Multispectral Camera System, consisting of six metric cameras using 9 x 9 inch film, with a weight (including gimbals) of 1124 Kg (2470 lb). This is followed by the Multiresolution Framing Camera System, with a weight (including gimbals) of 562 Kg (1235 lb). The total weight of the sensor payload is 2734 Kg (6009 lb).

Referring to Figure 5-9, the above two camera systems require the greatest amount of power, followed by the 20-band High Resolution Wideband Multispectral Scanner. The total sensor power requirements are 4.2 Kw (average) per day and 5.8 Kw (average) during the daily experimentation period of 16.6 hrs.

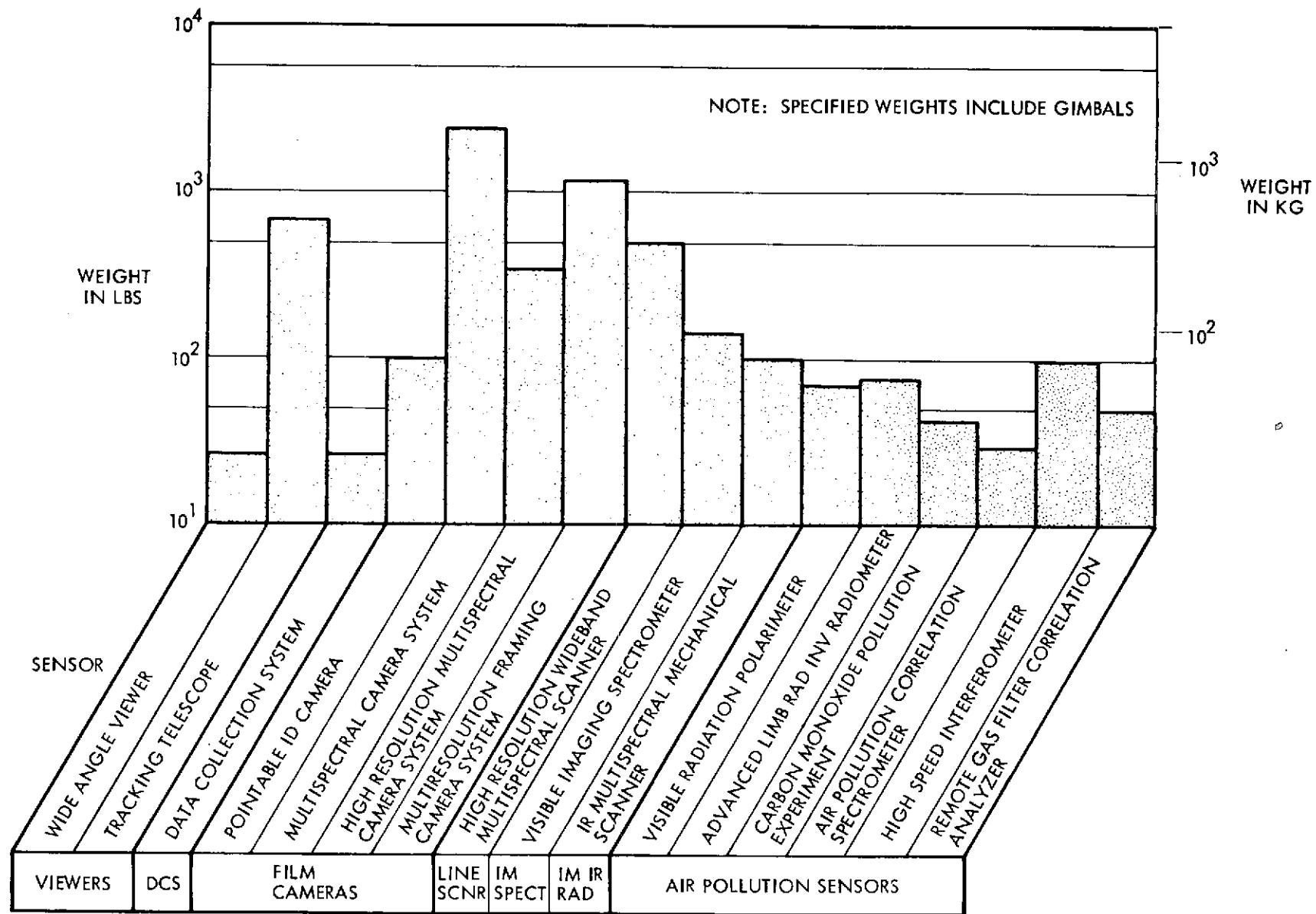


Figure 5-8. Summary - Weight of Experiment Sensors (Low-Cost Mission)

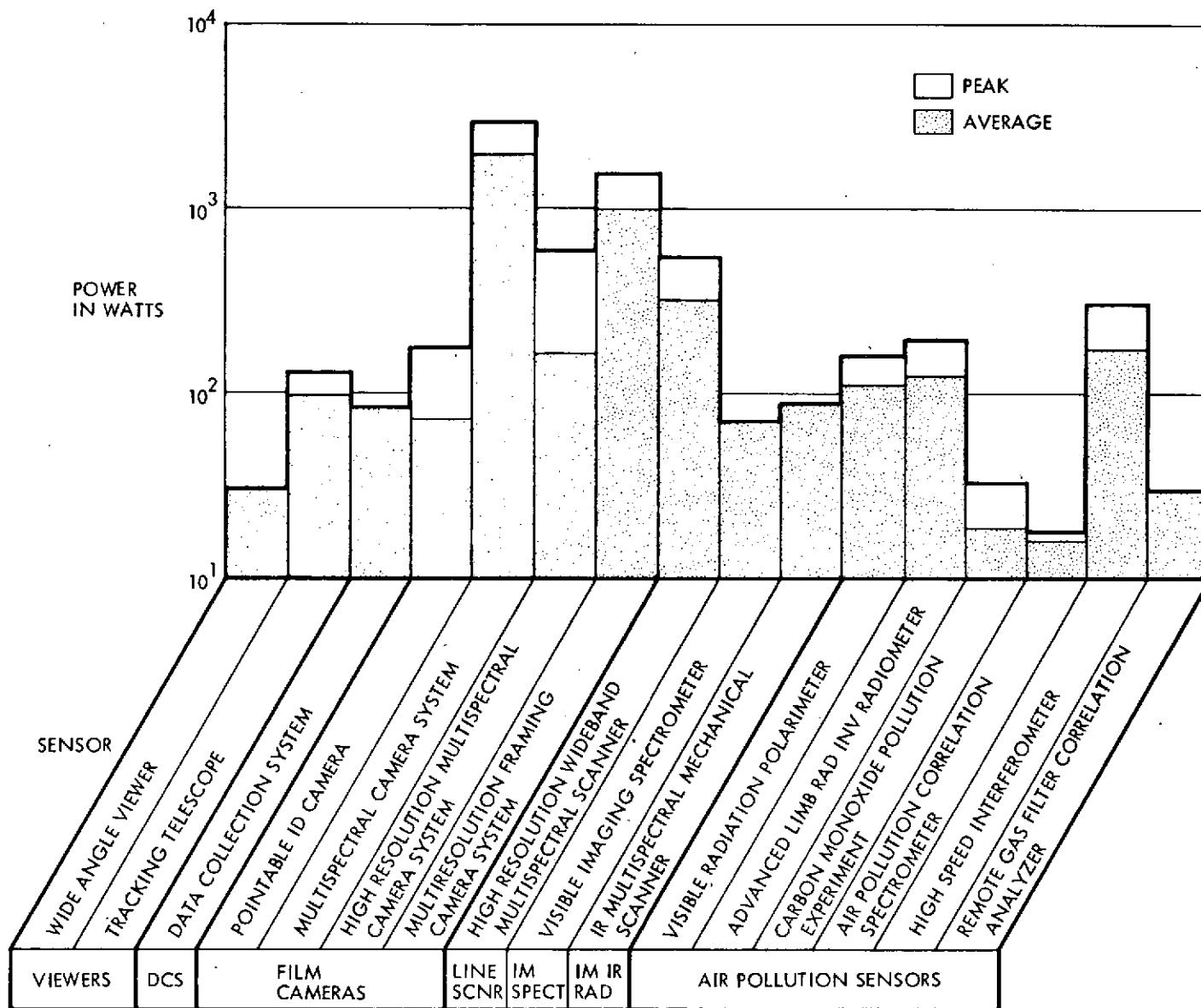


Figure 5-9. Summary - Power Requirements - Experiment Sensors (Low-Cost Mission)

N/A = NOT APPLICABLE

(1) = WITHOUT LINE BUFFERING AND STRETCHING

F = DATA RECORDED ON FILM

(2) = WITH LINE BUFFERING AND STRETCHING

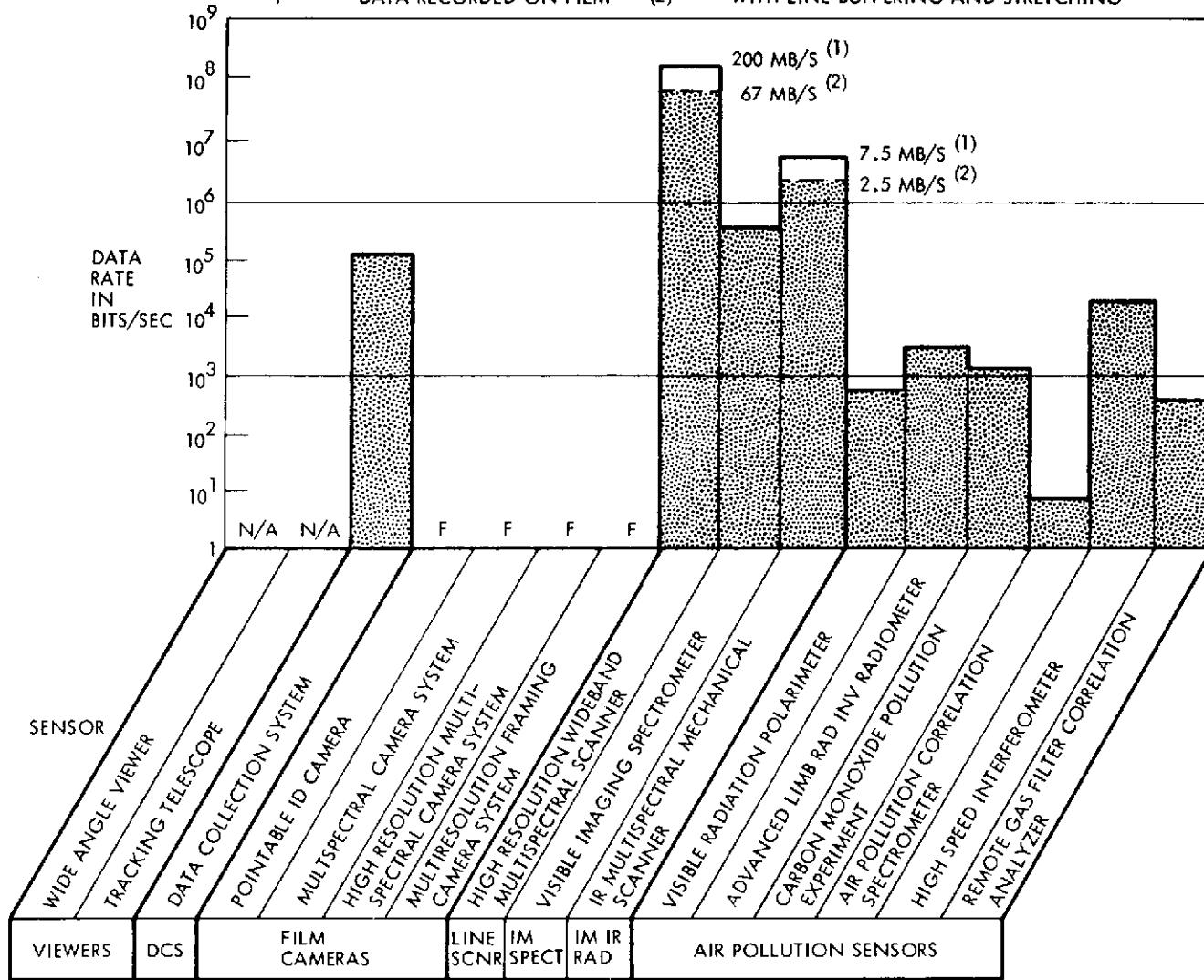


Figure 5-10. Summary - Data Recording Requirements - Experiment Sensors
 Low-Cost Mission)

Considering the data recording requirements (Figure 5-12), only the 20-band High Resolution Wideband Multispectral Scanner presents a significant data recording requirement. Assuming simultaneous use of all 20 spectral bands, the data rate is 200 MB/sec. However, the instrument uses a conical scan with only 120 degrees of the 360 degree scan being active, and by the use of data buffering and stretching the data rate can be reduced to a continuous value of 67 MB/sec.

This is followed by the IR Multispectral Mechanical Scanner, used to obtain thermal imagery of the sea surface. Maximum data rate is 7.5 MB/sec., and this instrument also has an active scanning duty cycle of 33 percent. Again, using line buffering and stretching of data, a continuous data rate of 2.5 MB/sec. can be obtained.

The balance of the sensors does not present a significant data recording requirement. The film cameras, which obtain the greatest amount of information (in the form of imagery on photographic film), have no data recording requirement, with the exception of annotation of data on a film data block.

5.2.2 Sensor Attitude Control, Stabilization, and Pointing

In the following section the attitude control, stabilization, and pointing requirements of the experiment sensors of the Manned Earth Observatory are considered, both from the standpoint of pointing and maintaining the stability of the lines of sight of the sensors during the earth observation intervals.

The pointing and stability capabilities of the Orbiter are first defined and then the requirements of the experiment sensors are identified. It is shown that in order to meet both the pointing requirements (accuracy and temporal duration) and the stabilization requirements of a number of the sensors, an auxiliary attitude determination system will be required.

To satisfy these requirements, TRW Systems recommends the use of a celestial-referenced, gyro-stabilized attitude determination system, an adaptation of the Precision Attitude Determination System (PADS), which has been developed by TRW Systems for the NASA Goddard Space Flight Center.

5.2.2.1 Orbiter Pointing and Stabilization Capability

From Reference 5-1, the payload pointing accuracy capability of the Orbiter is defined as follows:

The Orbiter is capable of pointing the payload continuously for one orbit every other orbit for one 24-hour period per mission at any ground, celestial, or orbital object within ± 0.5 degree. Payload requirements in excess of this capability should be provided by the payload or experiment systems.

From Reference 5-2, the payload stabilization capability of the Shuttle has been defined as follows:

	<u>With Baseline RCS System (1000 lbs.)</u>	<u>With 1000 lbs. and 25 lbs. RCS System</u>
Roll	0.0223 deg/sec	0.0023 deg/sec
Pitch	0.0143 deg/sec	0.0009 deg/sec
Yaw	0.0068 deg/sec	0.0004 deg/sec

The corresponding values in radians/second are:

	With Baseline RCS System (1000 lbs.)	With 1000 lbs. and 25 lbs. RCS System
Roll	3.9×10^{-4}	3.9×10^{-5}
Pitch	2.5×10^{-4}	1.6×10^{-5}
Yaw	1.2×10^{-4}	7.0×10^{-6}

5.2.2.2 Experiment Sensor Pointing and Stabilization Requirements

Table 5-1 lists the experiment sensors which will be utilized in either the baseline or low-cost missions. The pointing accuracy for each sensor has been estimated based upon the requirements of the experiments in which the sensors are used. For sensors with a wide angular field of view (e.g., framing cameras), the pointing accuracy specified represents a small fraction of the total field of view; this is still sufficiently large so that a stringent requirement is not placed on the attitude determination system. For sensors with a very small instantaneous field of view (e.g., No. 19, 20, 22, and 23), the pointing accuracies represent a considerable fraction of the IFOV but are still compatible with the pointing requirements of the experiment.

For the baseline mission, fifteen of the 29 sensors require a pointing accuracy more stringent than the 0.5 degree capability of the Orbiter for payload sensor pointing. For the low-cost mission, seven of the 16 sensors require pointing accuracy over and above the capability of the Orbiter (Figure 5-11).

Considering the temporal requirements of pointing, operation of all of the sensors specified for each of the two missions will be required on every orbit during the five days of operation of each mission in orbit. Thus, the constraint of the Orbiter capability, that of providing pointing during one orbit every other orbit for one 24-hour period during the mission, will not fulfill the mission requirements.

Thus, to meet both the accuracy and temporal requirements of sensor pointing, the use of an auxiliary attitude determination and pointing system is required. The PADS (Precision Attitude Determination System) is recommended by TRW Systems to meet this requirement. The accuracy of determination of attitude with this system, as will be presented in greater detail in a following section, is as follows:

Table 5-1. Experiment Sensor Pointing and Stability Requirements

No.	Sensor	Utilization by Mission		Pointing Accuracy Deg. (1s)	Spacecraft Stability (Rad/Sec)			Mount Stability (Rad/Sec)		
		Base-line	Low Cost		Roll	Pitch	Yaw	Roll	Pitch	Yaw
1	Tracking Telescope*	X	X	0.1 ⁽¹⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/C ⁽⁶⁾	0.14 x 10 ⁻³	0.14 x 10 ⁻³	N/C ⁽⁶⁾
2	Pointable Identification Camera*	X	X	1.0	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	2.7 x 10 ⁻³	2.70 x 10 ⁻³	N/C
3	Panoramic Camera	X		0.5	0.23 x 10 ⁻³	N/A ⁽⁵⁾	0.13 x 10 ⁻³	N/A	N/A ⁽⁵⁾	N/A
4	Wide Angle Framing Camera	X		1.0	N/A ⁽⁴⁾	1.3 x 10 ⁻³	1.35 x 10 ⁻³	1.35 x 10 ⁻³	N/A	N/A
5	Multispectral Camera System	X	X	1.0	N/A ⁽⁴⁾	2.0 x 10 ⁻³	4.0 x 10 ⁻³	2.0 x 10 ⁻³	N/A	N/A
6	High Resolution Multispectral Camera System	X	X	0.2	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	0.16 x 10 ⁻³	0.16 x 10 ⁻³	N/C
7	Multiresolution Framing Camera	X	X	0.5	N/A ⁽⁴⁾	2.7 x 10 ⁻⁴	5.4 x 10 ⁻⁴	2.7 x 10 ⁻⁴	N/A	N/A
8	High Resolution Wideband Multispectral Scanner	X	X	0.5	N/A ⁽⁴⁾	1.0 x 10 ⁻²	2.0 x 10 ⁻²	1.0 x 10 ⁻²	N/A	N/A
9	LWIR Spectrometer	X		0.3 ⁽¹⁾	4.0 x 10 ⁻²	4.0 x 10 ⁻²	4.0 x 10 ⁻²	N/A	N/A	N/A
10	Wideband Synthetic Aperture Radar	X		0.5	1.0 x 10 ⁻²	1.0 x 10 ⁻²	1.7 x 10 ⁻²	N/A	N/A	N/A
11	Multifrequency Wideband Synthetic Aperture Radar	X		0.5	5 x 10 ⁻³	5 x 10 ⁻³	8 x 10 ⁻³	N/A	N/A	N/A
12	Laser Altimeter/Scatterometer	X		0.1	3.2 x 10 ⁻¹	3.2 x 10 ⁻¹	N/C	N/A	N/A	N/A
13	Visible Imaging Spectrometer	X	X	1.0	3.3 x 10 ⁻³	3.3 x 10 ⁻³	6.6 x 10 ⁻³	N/A	N/A	N/A
14	IR Multispectral Mech. Scanner	X	X	1.0	2.0 x 10 ⁻³	2.0 x 10 ⁻³	4.0 x 10 ⁻³	N/A	N/A	N/A
15	High Resolution Visible Imaging Spectrometer	X		0.3	N/A ⁽⁴⁾	N/A ⁽⁴⁾	1.2 x 10 ⁻²	9.5 x 10 ⁻³	9.5 x 10 ⁻³	N/A
16	High Resolution IR Multispectral Scanner	X		0.3	N/A ⁽⁴⁾	N/A ⁽⁴⁾	2.7 x 10 ⁻²	2.0 x 10 ⁻²	2.0 x 10 ⁻²	N/A
17	Glitter Framing Camera			1.0	2.0 x 10 ⁻³	2.0 x 10 ⁻³	N/A ⁽⁴⁾	N/A	N/A	6.1 x 10 ⁻⁴
18	Star Tracking Telescope	X		0.25	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	4.7 x 10 ⁻⁸	4.7 x 10 ⁻⁸	4.7 x 10 ⁻⁸
19	UV Upper Atmosphere Sounder	X		0.1	5.6 x 10 ⁻¹	5.6 x 10 ⁻¹	N/A ⁽⁴⁾	N/A	N/A	1.7 x 10 ⁻¹
20	Visible Radiation Polarimeter	X	X	0.5 ⁽²⁾ / 0.1 ⁽³⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/C	1.7 x 10 ⁻⁴ (2) 1.7 x 10 ⁻⁴ (3)	1.7 x 10 ⁻⁴ (2) 1.7 x 10 ⁻⁴ (3)	N/A
21	Air Pollution Correlation Spectrometer	X	X	0.5	2.0 x 10 ⁻²	2.0 x 10 ⁻²	8.0 x 10 ⁻²	N/A	N/A	N/A
22	High Speed Interferometer	X	X	0.1	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	4.5 x 10 ⁻⁵ (2) 4.3 x 10 ⁻⁴ (3)	4.5 x 10 ⁻⁵ (2) 4.3 x 10 ⁻⁴ (3)	4.5 x 10 ⁻⁵ (2) 1.3 x 10 ⁻⁴ (3)
23	Carbon Monoxide Pollution Experiment	X	X	0.5 ⁽²⁾ / 0.1 ⁽³⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	1.7 x 10 ⁻³ (2) 6.5 x 10 ⁻⁵ (3)	1.7 x 10 ⁻³ (2) 6.5 x 10 ⁻⁵ (3)	N/C ⁽²⁾ 2 x 10 ⁻⁵ (3)
24	Cloud Physics Radiometer			1.0	2.5 x 10 ⁻²	2.5 x 10 ⁻²	2.0 x 10 ⁻²	N/A	N/A	N/A
25	Remote Gas Filter Correlation Analyzer	X	X	2.0 ⁽²⁾ / 0.1 ⁽³⁾	8.5 x 10 ⁻³	8.5 x 10 ⁻³	1.3 x 10 ⁻²	N/A	N/A	N/A
26	Adv. Limb Radiance Inversion Radiometer	X	X	0.1	N/A ⁽⁴⁾	N/A ⁽⁴⁾	N/A ⁽⁴⁾	3 x 10 ⁻⁵	3 x 10 ⁻⁵	6 x 10 ⁻⁵
27	TIROS-N Adv. Very High Resolution Radiometer	X		0.1	2.0 x 10 ⁻³	2.0 x 10 ⁻³	6.1 x 10 ⁻⁴	N/A	N/A	N/A
28	TIROS-N Operational Vertical Sounder	X		0.5	2.0 x 10 ⁻³	2.0 x 10 ⁻³	2.4 x 10 ⁻³	N/A	N/A	N/A
29	Passive Microwave Radiometer	X		0.5	1.9 x 10 ⁻³	1.9 x 10 ⁻³	3.8 x 10 ⁻³	N/A	N/A	N/A
30	Microwave Radiometer/Scatterometer			0.1	2.0 x 10 ⁻³	2.0 x 10 ⁻³	2.0 x 10 ⁻³	N/A	N/A	N/A
31	Sferics Receiver			5.0	N/C	N/C	N/C	N/C	N/C	N/C
32	Wide Angle Viewer/Hydrogen Alpha Line Viewer*	X	X	2.0 ⁽¹⁾	N/C	N/C	N/C	N/C	N/C	N/C
33	Data Collection System	X	X	N/C	N/C	N/C	N/C	N/C	N/C	N/C
34	Precision Attitude Determination System*	X	X	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Common Core Experiment Sensor

(1) Manual Pointing by Astronaut
 (2) Earth-Pointing Mode
 (3) Limb-Pointing Mode
 (4) Not Applicable, Sensor Mount Provides Isolation from S/C
 (5) Sensor Provides IMC
 (6) N/C = Not Critical

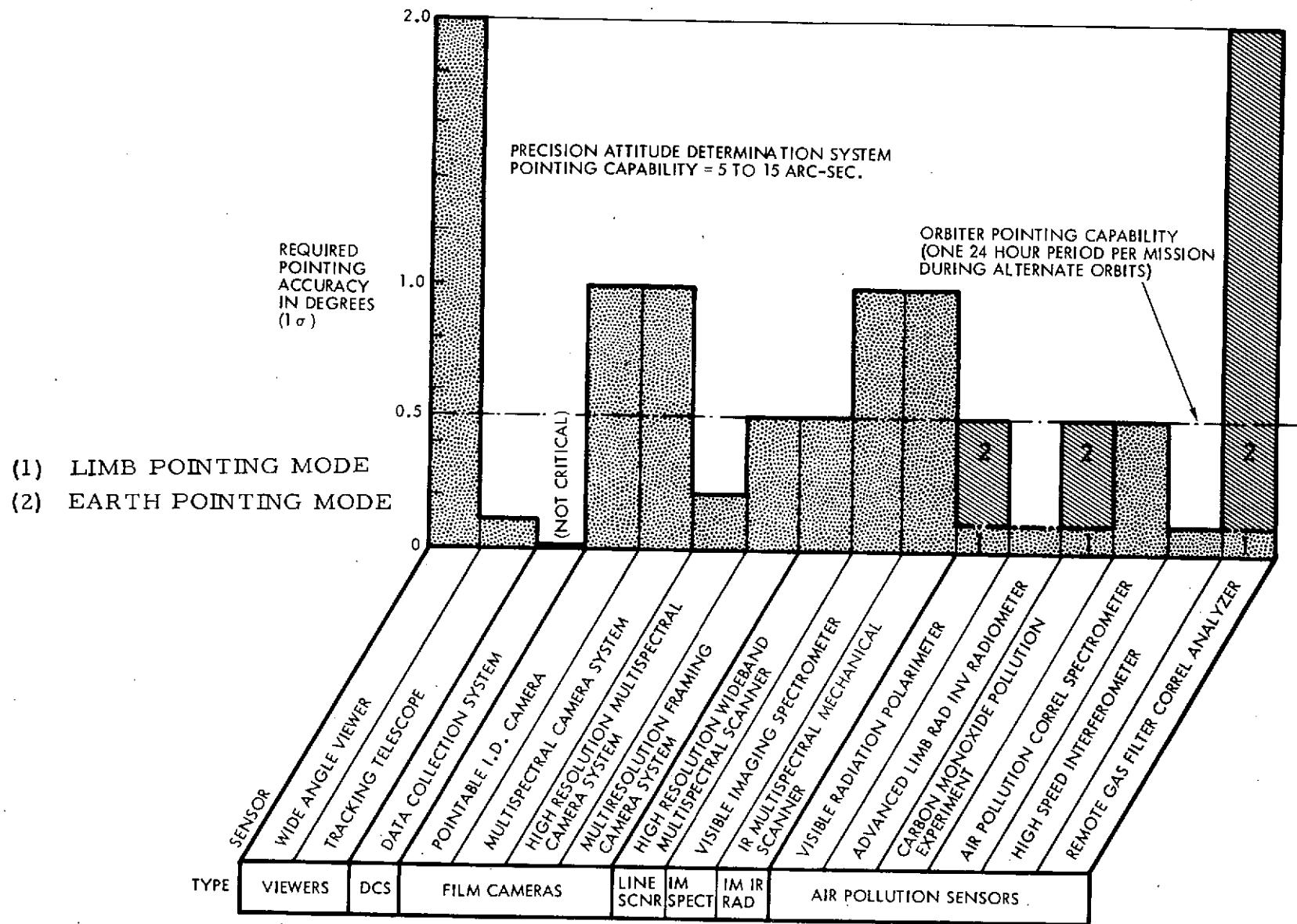


Figure 5-11. Experiment Sensor Pointing Requirements
(Low-Cost Mission)

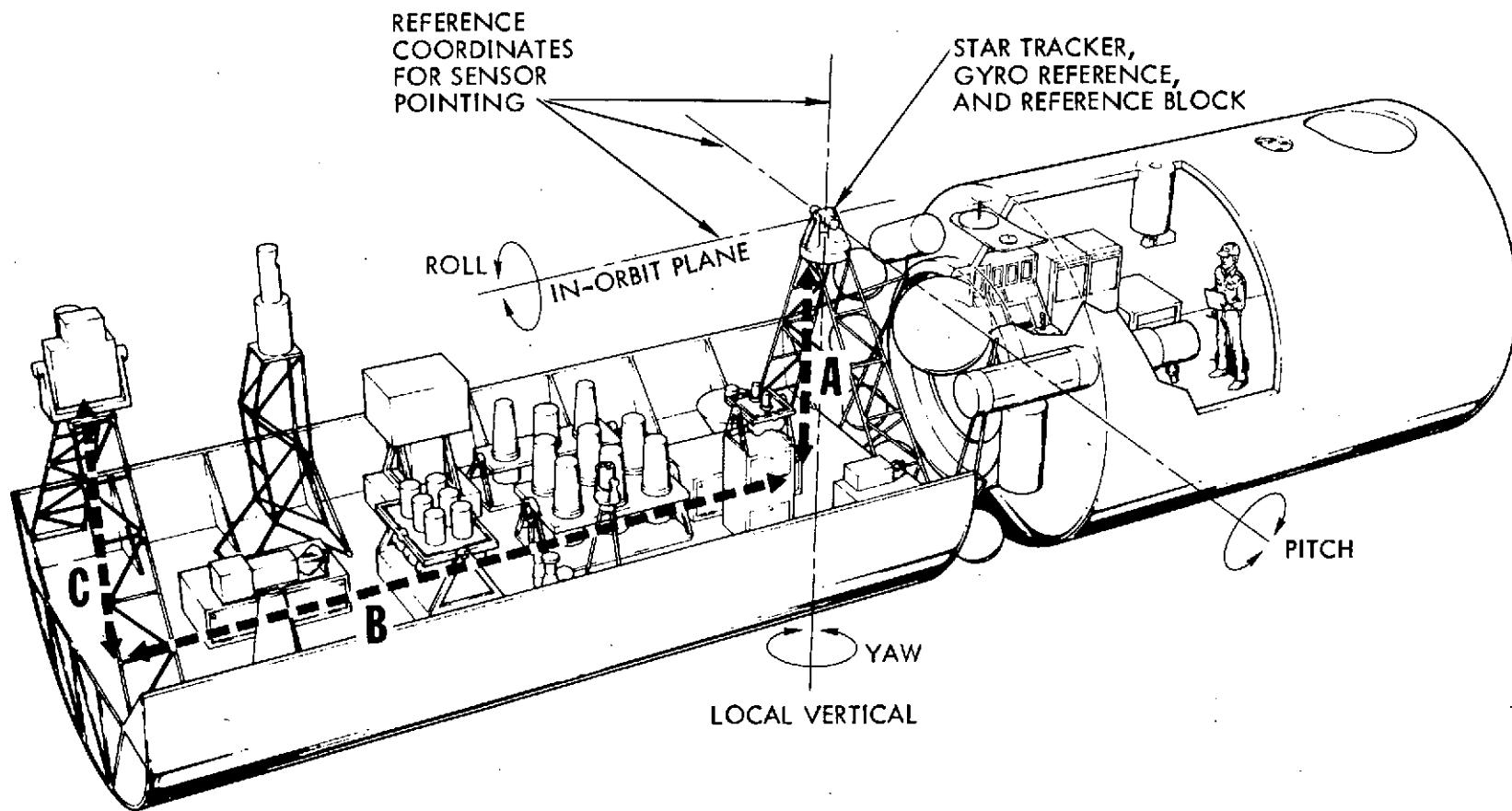
- a) Attitude with respect to inertial space, in celestial coordinates: 0.001 degree, or 3.6 arc-seconds, one sigma, per axis.
- b) Attitude relative to the local vertical reference (e.g., roll, pitch, and yaw), in which the inertial attitude is combined with on-board ephemeris data: 14.2 arc-seconds, one sigma, per axis (assuming a 0.25 n. mi. error in knowledge of ephemeris, which contributes a 14.0 arc-second error in experiment pointing).

Note that the above specified values do not include the additional error contribution of structural misalignments and thermal distortion of structure between the attitude determination system and sensor mounts. Errors from this source, if sufficiently large, can be maintained to a very low value, on the order of a few arc-seconds, by the use of automatic alignment monitoring using optical autocollimation between the reference base of the PADS system and the sensor mounts (see Figure 5-12).

In Table 5-1, the stabilization requirements of each of the sensors for the two missions have also been estimated. In configuration, the sensors vary from those using a strapdown (no-gimbal) configuration, to those using one, two, or three gimbals. Generally, the use of gimbals has been employed whenever feasible in order to permit pointing of the sensors out of the orbital plane to permit observation of areas which otherwise could not be observed if a strapdown sensor configuration were used. This approach has been used in order to maximize the amount of data which can be obtained during the relatively short (five-day) duration in orbit.

In the case where a sensor does not use gimbals (strapdown configuration), the stability of the line-of-sight of the sensor will be determined entirely by the stability characteristics of the Orbiter. Where a three-gimbal configuration is used, the stability of the line-of-sight of the sensor can be determined solely by the stability characteristics of the PADS celestial-inertial attitude determination system. Where only one or two gimbals are used, the stability of the non-gimballed axes will be dependent upon the Orbiter, and the stability of the gimballed axes will be dependent upon the PADS attitude determination system.

Comparing the values of the required spacecraft stability in roll, pitch, and yaw from Table 5-1 with the capabilities previously specified



- A** - AUTOCOLLIMATOR TRANSFERS REFERENCE FRAME TO PALLET STRUCTURE
- B** - AUTOCOLLIMATOR TRANSFERS REFERENCE FRAME ALONG PALLET STRUCTURE
(NOT REQUIRED IF STRUCTURAL RIGIDITY < SENSOR POINTING ACCURACY)
- C** - AUTOCOLLIMATOR TRANSFERS REFERENCE FRAME FROM PALLET TO SENSOR
(REQUIRED ONLY IF SENSOR IS DEPLOYED FROM PALLET)

Figure 5-12. Precision Attitude Determination System for Experiment Sensor Pointing

in Section 5.2.2.1, it is seen that the capabilities of the Orbiter will be satisfactory for sensor stabilization, using either the Baseline RCS system (1000 lb.), or the 1000 lb. RCS system with the addition of a 25 lb. RCS system.

Considering the mount stability requirements defined in Table 5-1, these must be satisfied by the capabilities of the PADS attitude reference system. The PADS will utilize high quality inertial quality gyros with a short-term random drift rate in the order of 0.001 deg/hr, or 4.7×10^{-9} radians/sec. Comparing this value to the requirements for mount stability defined in Table 5-1, it is seen that the PADS attitude reference system will fulfill the mount stability requirements for all of the sensors listed for either of the two missions.

5.2.2.3 Precision Attitude Determination System

Pointing requirements of 0.1 deg. have been identified for a number of the experiment sensors. The attitude control capability of the Orbiter is ± 0.5 deg. and this is available to the payload only during one day of the five days in orbit. To satisfy the pointing requirement, an attitude determination system is recommended for use as part of the experiment payload. This system will be used to determine the inertial attitude of the pallet and, in conjunction with ground provided ephemeris and targeting data, to point the instrument gimbal(s) to the desired accuracy. The attitude determination system proposed is an adaptation of the Precision Attitude Determination System (PADS) developed by TRW for NASA/GSFC. Key elements of this system include a gimballed star tracker, a three-axis gyro package for short term attitude data, and on-board computation capability.

PADS determines the inertial attitude of the spacecraft by means of periodic sightings of selected stars stored within its star catalog. For this application, a single-gimbal star tracker is used with its gimbal axis oriented to rotate the tracker boresight in a plane normal to the orbit plane. Stars are acquired by commanding the proper gimbal angle which will allow the star tracker field of view (0.5 deg.) to acquire the star as the spacecraft advances in orbit. During intervals between star sightings (several minutes), the attitude is extrapolated in the computer based upon gyro data. Continuous attitude information is available at

at all times. The inertial attitude is combined with ground updated ephemeris data to provide the geocentric attitude necessary for instrument pointing. A functional diagram of the Precision Attitude Determination System is illustrated in Figure 5-13.

In order to obtain an adequate field of view for the star tracker, it is placed on an elevated platform (Figure 5-12). The inertial attitude is therefore determined with respect to reference axes contained in this platform. To determine the attitude of the pallet, the orientation of this platform is measured by an autocollimator located on the pallet. The autocollimator measurements are combined with the attitude data to obtain the pallet attitude. The autocollimator readings need only be made periodically. Gimbaled instruments mounted on deployable structures may require autocollimators to determine their orientation with respect to the pallet. Alternatively, a direct autocollimation between the instrument and the PADS mounting platform could be accomplished.

Sensor Pointing — Selected targets on the surface of the earth can be defined relative to inertial space (right ascension and declination), relative to earth fixed coordinates (latitude, longitude, and radius), or relative to local vertical coordinates (roll, pitch, yaw). Target coordinates are stored with a time-tag for proper sequencing. On-board targeting equations determine the line-of-sight vector from the spacecraft to the target which is then transformed into instrument gimbal base coordinates. Steering equations utilize the target vector coordinates in the gimbal base reference frame to generate gimbal angle commands to point the instruments.

Physical Characteristics — The PADS system is designed for use in a three-axis stabilized spacecraft, without constraints on the orbit or spacecraft stabilization. The physical characteristics of the system are summarized in Table 5-2. The PADS assembly and hardware components are illustrated in Figure 5-14. The sensors and electronics are shown as configured for a representative spacecraft equipment module (represented by the cut-away walls); thermal shielding associated with the star tracker has been deleted for clarity. The star tracker and gyro assembly are mounted and aligned on the reference block. Mounting of the electronics is not critical. The reference block is mounted within the spacecraft,

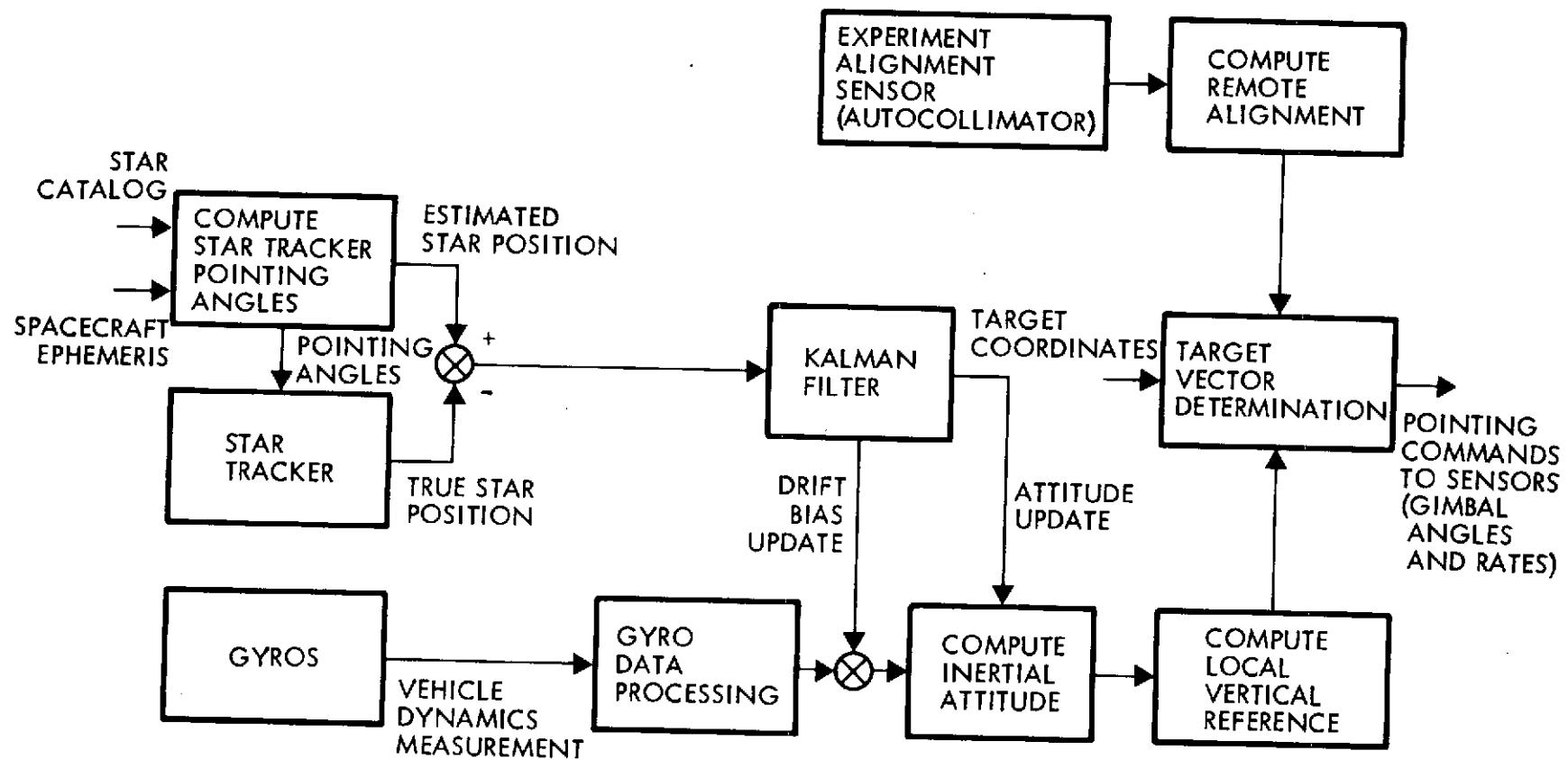
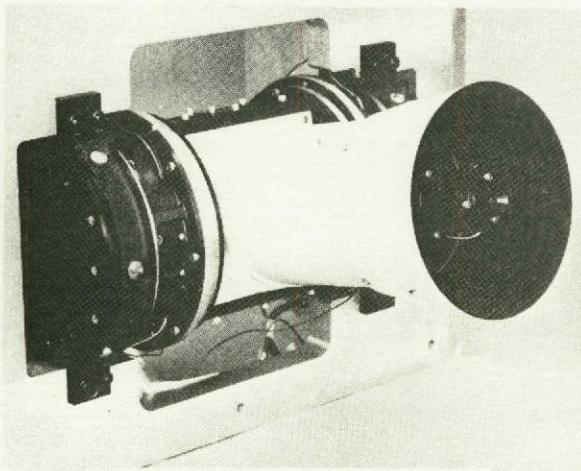
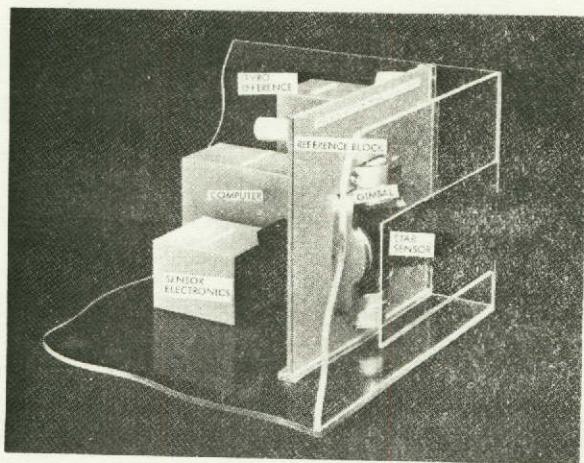


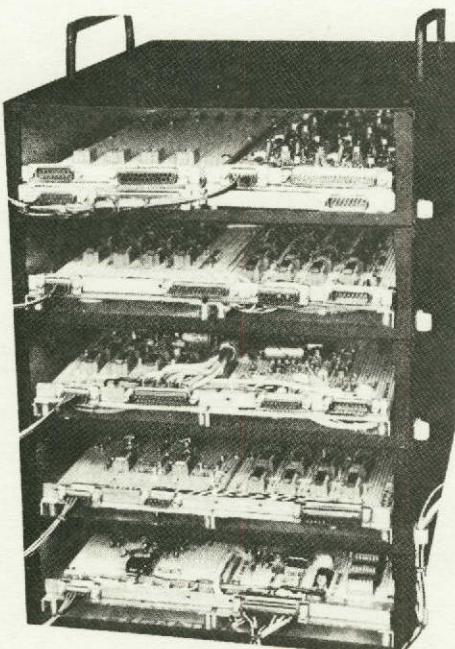
Figure 5-13. Functional Diagram — Precision Attitude Determination System (PADS)



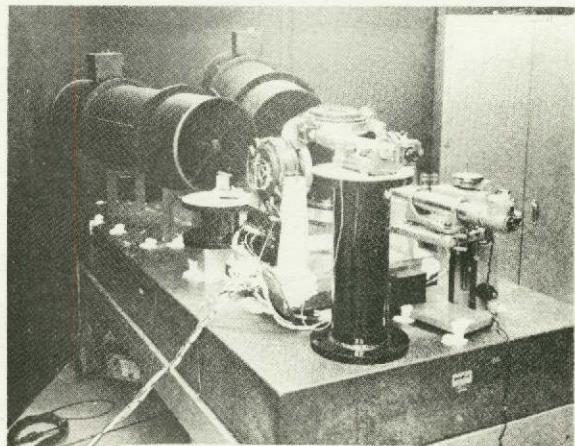
Star Tracker Assembly



Gyro Reference Assembly



Sensor Electronics Assembly



Star Tracker Test

Figure 5-14. PADS Assembly and Components

with an appropriate clear FOV made available for the star tracker. For sensor payloads non-integral to the reference block, alignment sensors (autocollimators) may be employed. Data rates on the order of 200 bps are adequate and present no significant interface requirement on the spacecraft.

Table 5-2. Summary of PADS Physical Characteristics

Assembly	Wt-Kg (lb)	Power (Watt)	Envelope-cm (in.)
Star Tracker Assy (STA)	11.4 (25)	6	18 x 23 x 51 (7 x 9 x 20)
Sensor Elect Assy (SEA)	2.3 (5)	15	10 x 20 x 20 (4 x 8 x 8)
Gyro Ref Assy (GRA)	4.1 (9)	10	15 x 15 x 15 (6 x 6 x 6)
Ref Block Assy (RBA)	4.5 (10)	0	-- --
Digital Computer Assy (DCA)	1.8 (4)	13	-- --
Integration Hardware	<u>1.8 (4)</u>	<u>0</u>	-- --
	25.9 (57)	44	
Attitude Transfer Units (if required)	(10)	9	12.5 dia. x 25 (5 dia x 10)

Performance Capability — Based upon tests which have been conducted at TRW Systems on components of the PADS System, a representative budget for determination of attitude in local vertical (roll, pitch, yaw) coordinates is as defined in Table 5-3.

An additional source of error is that due to mechanical misalignment by thermal deformation of the structure between the PADS attitude determination system and the experiment sensor which is pointed at the desired target. If errors due to these sources exceed the required pointing accuracy of the sensor, automatic optical autocollimation between the PADS reference block and the sensor mount can be used to either monitor or correct this error. In tests completed at TRW, the accuracy of optical autocollimation, using equipment developed in the PADS program, has been in the order of 2 arc-seconds.

Table 5-3. Performance Characteristics
Precision Attitude Determination System

- ACCURACY OF REFERENCE FRAME FOR EXPERIMENT POINTING
(LOCAL VERTICAL - ROLL, PITCH, YAW COORDINATE SYSTEM)

<u>ERROR SOURCE</u>	ERROR (ARC-SEC, ONE SIGMA, FOR EACH OF 3 AXES)	
STAR TRACKER	1.77	
SENSOR ELECTRONICS	0.63	
GYRO REFERENCE	1.18	
REFERENCE BLOCK	0.50	
DATA PROCESSING	0.35	
EPHEMERIS ERROR (0.1 N MI) (0.25 N MI)	5.5	14.0
TOTAL (RSS)	5.9	14.2
		ARC-SEC/AXIS (EXCLUDING ERRORS DUE TO S/C STRUCTURAL DEFORMATION)

- AUTOCOLLIMATOR ATTITUDE TRANSFER ACCURACY
~ 2 ARC-SECONDS (PER UNIT)
- COORDINATE REFERENCE FRAME STABILITY
0.001 DEG/HR (4.7×10^{-9} RAD/SEC) PER AXIS

Developmental Status -- The PADS system concept has been developed at TRW under contract to NASA/GSFC since 1970. Design studies, simulation, and error analyses have demonstrated its performance potential. The key hardware elements (star tracker, gyro reference, and autocollimator) have been built and tested in the form of either engineering or breadboard models. A laboratory test of the complete PADS system will be conducted during FY 1974 under the sponsorship of the NASA Advanced Applications Flight Experiment (AAFE) Program.

The star tracker is a precision gimbaled null-tracking sensor developed by TRW Systems. The tracker has 0.5 degree Cassegrain optics with an 84.5 cm focal length and 42 cm² aperture.

The detector is a deflectable photomultiplier tube with a photocathode of S-20 spectral response. The gimbal angle encoder uses a 4-inch inductosyn.

Several existing gyro packages are suitable for PADS such as the Honeywell unit for the ATS-F package. TRW (with Northrop) and Honeywell also have developed gyro packages with suitable characteristics under NASA contract for SAS-D.

The computation requirements for pointing of the sensors to the selected targets can be satisfied by state-of-the-art aerospace computers such as the Honeywell HDC 401 (built for the ATS-F program), or the CDC Model 469 computer.

An automatic optical autocollimator has been built and tested for TRW Systems by Barnes Engineering as part of the PADS program.

5.2.3 Sensor Control and Display Requirements

For the 16 sensors used in the Low-Cost Pollution mission, preliminary data defining interface functions has been developed in order to define the control and display requirements for the mission. In addition, preliminary interface data was developed for the Precision Attitude Determination System (PADS), used to establish a coordinate reference frame and for use in pointing of the sensors.

This detailed data is presented in Appendix B.

REFERENCES

- 5-1. "Space Shuttle, Baseline Accommodations for Payloads," Document No. MSC-06900, NASA Manned Spacecraft Center, Houston, Texas, June 27, 1972.
- 5-2. Space Shuttle Presentation to Earth Observations Working Group, November 16, 1972.

6.0 CREW FUNCTIONS AND ACCOMMODATIONS

Mission data derived from the pallet-mounted sensors are transmitted via a data bus and dedicated signal paths to the Sortie Lab for processing, recording, and display to the crew. Inasmuch as the conceptual design for data management and other subsystems was based upon a set of requirements developed from crew size and crew function allocations, it is appropriate to present this information as an introduction to the detailed description of the configuration and subsystems comprising the Sortie Lab Common Core Equipment.

6.1 CREW ACTIVITY DESIGN GUIDELINES

System functions assigned to the MEO crew were developed from a set of guidelines aimed toward increasing the flexibility, efficiency, and reliability of system operation and data collection. Guidelines are listed here:

- 1) Utilize the crew for on-board decision-making and system monitoring to insure that full use is made of all data collection opportunities during the 7-day mission. Crew should be responsible for evaluating sensor status and weather conditions before and during data-taking sequences, and should have a capability for selecting an alternate pre-stored experimental plan if the primary plan will not yield useful data on that target pass.
- 2) Crew functions should be selected to increase flexibility and efficiency of data collection while at the same time minimizing vulnerability of the data collection system to operator error resulting from overload, time pressure, and fatigue. For example, the time-line for powering, calibrating, activating, and pointing multiple sensors on a split-second schedule is too complex for manual operation. The mission plan should, therefore, be stored and implemented in the on-board computer, with pre-computed backup data-taking sequences, stored in the computer, available for activation by the crew through a simple command entry. One mode of operation of the system utilized under standardized routine conditions where the need for human decision-making does not arise, should allow for automatic data-collection without a requirement for real-time operator intervention.
- 3) The data management system should be designed to allow the crew to direct and supplement this wholly automatic capability not only through real-time intervention and assistance to the automatic system, but also through post-pass evaluation and compression of data for permanent storage and priority transmission to the ground. The primary value of the crew for earth observation missions lies in these functions. The data-

gathering capability of the sensor ensemble far exceeds the data-link capability to transmit information to the ground for evaluation and mission direction since, aside from the camera and telescope instruments, only about 8 percent of the line-scan and other electronic sensor outputs can be sent to the ground utilizing all available transmission opportunities.

The severity of the problem of real-time transmission of sensor outputs to the ground for decision-making and mission direction is best illustrated through consideration of the High Resolution Wideband Multispectral Scanner, whose output, after buffering and stretching, is 67 MB/S. It is possible to transmit imagery selected by the crew as critically important to the ground through the data link facilities provided in the current Shuttle design capabilities and guidelines. Without such filtering to identify data of unusual importance, multispectral imagery cannot be transmitted for ground evaluation and mission direction.

Displaying the flood of information derived from groups of instruments active during a multi-discipline data taking pass to the crew and having them evaluate it all on a real-time basis is not feasible. Operator intervention on a real-time basis in the automatic data-taking sequence must be highly selective, based on combinations of automatic and manual recognition of signatures of phenomena of interest. This will probably require some real-time automatic processing of low data rate sensors for signature analyses, plus a sophisticated display capability permitting the crew to carry out manual signature recognition in the displayed sensor data. Other important crew functions during data-taking sequences should include visual search through the telescopes for targets of opportunity, filtering and screening out of false alarms in the automatic signature analysis outputs on the basis of telescope viewing and correlation of the data from several sensors, voice annotation of recorded data, and flagging of interesting data sequences for post-pass review and analysis.

4. Full advantage should be taken of crew capabilities for post-pass analysis of recorded data. In the model missions examined to date, data-taking sequences are relatively short, typically extending over a 5 to 10 minute period on each orbit. Crew, computer, and displays are thus available during the major portion of each orbit for playback and analysis of recorded data without the rigid time constraints of real-time data collection. Playback analyses can involve several functions. These include selection of sensor sequences containing unusual or unexpected phenomena for immediate transmission to the ground for mission replanning. Such replanning would be undertaken to increase coverage of an interesting target area on a subsequent pass, as well as reconfiguration of individual sensors, pointing angles and combinations of sensors on the basis of sensor performance or malfunction. Similarly, the amount of time devoted to

individual experiments during the mission could be adjusted on the basis of the results obtained during the first day or two of data collection.

Replay analysis can also serve as the basis for initial screening of recorded data to delete sequences of little or no interest and value so that tape reels can be used again in an attempt to gather data of greater usefulness during subsequent data-taking sequences.

- 5) Utilization of the crew for onboard data screening to reduce the amount of low-value sensor data returned for ground processing permits the use of data-collection strategies which show promise of greater efficiency and flexibility than those considered to date. The model missions analyzed in this study have presumed that ground areas for sensor coverage were selected by Principal Investigators in advance, so that a detailed mission plan could be prepared prior to each MEO flight. It is apparent, however, that in many cases the investigator will want to have particular phenomena recorded, but will not be able to specify the exact times and locations for their appearance. A typical example might be an agricultural investigator interested in testing new techniques for the early identification of crop disease vectors. He will have devised and perhaps tested on low-altitude imagery algorithms for automatic signature analysis, and now wants to develop these techniques for automatic early identification of plant disease in multi-spectral imagery from orbital platforms. The algorithms already developed may have been reasonably successful in identifying fully-developed plant disease outbreaks in prior ground truth tests, but their power in identifying areas of potential crop damage early enough to permit effective remedial efforts needs to be tested and developed. These algorithms may produce a high rate of false positive identifications, such that wholly-automatic imagery collection based on these algorithms would drown the data storage capabilities of the system. It should be possible to design the MEO data management system and man-machine interface so that the crew can, in real-time or in post-pass playbacks, scan the imagery and use their pattern and signature recognition skills and information from other sources to filter and compress the automatically-tagged imagery so that the amount permanently stored onboard for subsequent ground processing represents a reasonable match between resources required and the potential value of the data acquired.

The general approach illustrated above would allow groups of sensors to be operated fairly continuously, within power constraints and other considerations, over portions of the ground track which might yield data of value, utilizing the crew to screen data held in temporary storage to delete segments of low potential value and retain for permanent storage information most germane to the needs and interests of the user community. This general approach is difficult to utilize in initial attempts at quantitative sizing of system configurations, and has not been investigated in depth during this phase of the MEO study. The

Sortie Lab Common Core Equipment configuration described in following sections can be adapted to support this mode of data collection without significant change. The value and requirements of implementing this approach in a baseline MEO design will be investigated in depth in the follow-on phase of this study.

- 6) The Shuttle Orbiter capabilities for supporting a four to six man payload crew should be employed to full advantage in developing a cost-effective earth observatory conceptual design. Potential crew functions should be examined to assess the feasibility of tasking the crew with critical system functions for which the current state of the art provides no means of accomplishment without a significant development effort, thus lessening system dependence on the cost and risk of SOA advancements.
- 7) The Shuttle earth observatory payload will operate in a fairly autonomous mode, with minimum ground monitoring and support. Full utilization of man's capabilities to carry out complex scientific tasks efficiently and effectively on an 12-hours a day work schedule requires careful attention to man-machine interface design. It is desirable to avoid the necessity for extreme standards in crew selection so that not only can Principal Investigators and other trained scientists serve as crew members, but that this be possible with a moderate amount of special indoctrination and training. Accomplishing these goals calls for careful selection of display/control equipments and information presentation formats, work place arrangement, division of duties, and other accommodations for minimizing workload and fatigue in a low-g environment.

6.2 CREW TIME LINE - LOW-COST POLLUTION MISSION

The preliminary concept of crew functions presented here was developed in accordance with the guidelines and constraints established by MSFC in the Sortie Lab Design Requirements document of 1 December 1972. It is based upon a payload-dedicated crew of four, each of whom spends eleven hours per day in scheduled MEO tasks. As shown on pages D-1 through D-18 of Appendix D, Volume II of this report, data taking is interrupted for approximately eight hours while the continental United States and adjacent areas are in darkness. This provides a common sleeping interval for the crew with relief periods for crew members interspersed during the 16-hour operational period for rest and personal maintenance. This schedule provides for manning of the Sortie Lab on the following basis:

<u>On Duty Per 24-Hour Period</u>	
Four crew members	2 hours
Three crew members	8 hours
Two crew members	6 hours
Total	<u>44</u> hours

A two-orbit segment of a representative mission timeline for the low-cost sensor configuration is shown in Figure 6-1. It shows experiments activated during each orbit, data taking sequences for individual sensors, and crew activities on a common timeline. Individual crew members engaged in each of these gross activity categories are designated by A, B, C, and D. A number of console design requirements and system characteristics are described in the context of the following summary description of these crew functions.

6.2.1 Pre-Target Acquisition Activities

Mount and Label Tape Reels. Two 100-track tape recorders are required for data storage, playback, data compression, and data-link transmission of high-priority imagery to the ground. Under typical conditions of operation, a 2000-ft reel of tape will accommodate ten minutes of data acquisition. Utilization of the crew to change tape reels permits the use of recording equipment currently under development to handle the demands of this application.

EXPERIMENTS

REGIONAL WATER POLLUTION EXPERIMENT
 AIR POLLUTION MONITORING
 INTERNATIONAL METROPOLITAN AREA BIENNIAL UPDATE
 COASTAL GEOLGY AND GEOMORPHIC PROCESSES
 LAKE EUTROPHICATION

SENSORS

TRACKING TELESCOPE
 POINTABLE IDENTIFICATION CAMERA
 WIDE ANGLE VIEWER
 MULTISPECTRAL CAMERA SYSTEM
 HIGH RESOLUTION MULTISPECTRAL CAMERA
 MULTIRESOLUTION FRAMING CAMERA
 HIGH RESOLUTION WIDE BAND MULTISPECTRAL SCANNER
 VISIBLE RADIATION POLARIMETER
 AIR POLLUTION CORRELATION SPECTROMETER
 HIGH SPEED INTERFEROMETER
 CARBON MONOXIDE POLLUTION EXPERIMENT
 REMOTE GAS FILTER CORRELATION ANALYZER
 ADVANCED LIMB RADIANCE INVERSION RADIOMETER
 DATA COLLECTION SYSTEM
 VISIBLE IMAGING SPECTROMETER
 IR MULTISPECTRAL MECHANICAL SCANNER

CREW FUNCTIONS

MOUNT AND LABEL TAPE REELS
 BRIEFING MATERIALS FOR NEXT PASS
 MONITOR SENSOR CALIBRATION
 WIDE ANGLE VIEWER OPERATION
 SELECT ALTERNATE EXPERIMENT
 REAL-TIME SENSOR MONITORING
 TRACKING TELESCOPE OPERATION
 EVALUATE DATA TAPE PLAYBACK
 VOICE COMMUNICATION WITH GROUND
 PRIORITY DATA TAPE FOR DATA LINK
 ENTER MISSION PLAN CHANGES
 SCHEDULED TAPE RECORDER MAINTENANCE
 OFF DUTY (REST AND SELF-MAINTENANCE)

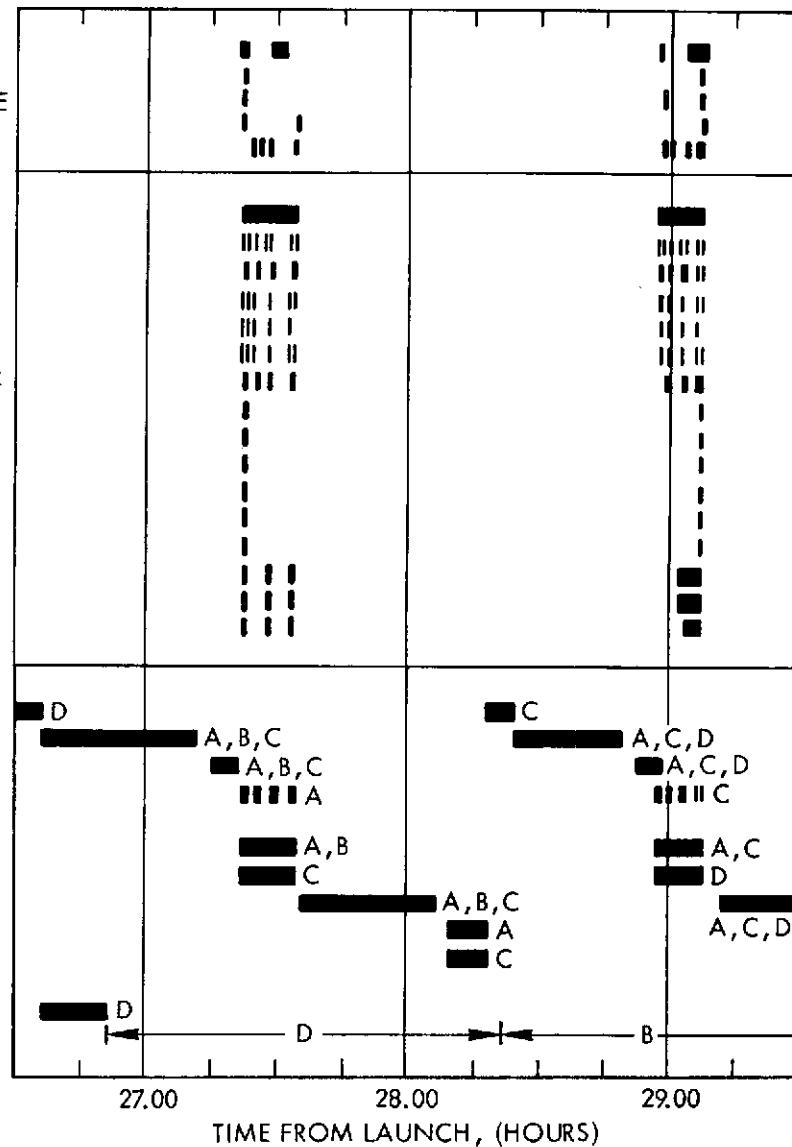


Figure 6-1. Representative Timeline – Low-Cost Pollution Mission

Briefing Materials for Next Pass. During each of approximately 55 orbits, the crew must identify data acquisition areas and point targets with the wide-angle viewer and tracking telescope, be prepared for the sequence of sensor activations, know the signatures of interest for the particular experiments activated (as well as the display formats most useful for real-time monitoring). A period of 20 - 30 minutes preceding each pass is allocated to this activity. Crew consoles include two types of display equipment to present briefing materials. The first is a microfiche viewer in which are stored maps, imagery, reference signatures, and other reference materials assembled prior to launch and called up for viewing under operator command through the computer keyboard at the console. At the same time the crew member has a CRT display of the computer-stored timeline of experiments and sensors to be activated in the next data-taking sequence. Retrieval of microfilmed reference materials is keyed to the computer-stored mission schedule displays, so that crew members can access the briefing materials relevant to their particular responsibilities on that orbit.

Monitor Sensor Calibration. Sensor calibration is a computer-controlled sequence initiated as close to target acquisition as possible. Graphic calibration formats are prepared for display to the crew, and the computer alerts the crew to values outside of stored limits. In the event of sensor malfunction, the crew can select an alternate mission plan, stored in computer memory, to optimize data acquisition until the problem is diagnosed and corrected.

Wide-Angle Viewer Operation. The wide-angle viewer is used for general orientation and evaluation of weather conditions in the target area. In the minute or two preceding sensor activation the Mission Director will check the extent of cloud cover and decide whether to proceed with the primary mission plan or select a pre-computed alternate. The wide-angle viewer must be mounted adjacent to a crew console so that it can be used in conjunction with CRT and microfilm displays. The wide-angle viewer image is also used by the tracking telescope operator for orientation in locating point targets and searching for targets of opportunity. A TV display of the wide-angle viewer image with superimposed cross-hairs defining the tracking telescope pointing angles should therefore be made available at other crew consoles.

Real-Time Sensor Monitoring. During data acquisition the crew monitor sensor performance, carry-out voice annotation for later merging with sensor records, search for signatures of interest in the sensor displays, and flag interesting data sequences for post-pass review and analysis. Some real-time intervention in data collection is possible on the basis of the crew's ongoing evaluation of imagery and signatures, since sensor pointing can be slaved to the pointing angles of the telescopes, with data acquisition commanded manually through console controls.

Tracking Telescope Operation. One crew member is totally occupied with tracking telescope operation during experiment operation. In addition to manual pointing of slaved sensors described above, he will search for targets of opportunity and carry out a detailed annotation of viewing conditions.

6.2.2 Post-Pass Activities

Evaluate Data Tape Playback. The on-duty crew will work in parallel to review tape-recorded sensor records with a minimum of 30 minutes available for this activity. In addition to checking the integrity of the taped data, the crew will carry out more intensive analyses of sequences flagged during data acquisition, and scan through additional data frames with computer processing assistance. The computer will be employed to format frames of multispectral imagery and prepare false color and multi-color displays of selected spectral bands. With several high-resolution color displays at each console and a dedicated computer available to process and display the output of non-imaging pollution sensors, the crew will evaluate and further annotate these records, while at the same time selecting individual display frames for transmission to the ground on subsequent data-link transmission opportunities.

The review techniques for the pollution mission can include:

- Display of imaging sensor data
- Coordination of non-imaging sensor spot location with the imaged data
- Display of non-imaging signatures
- Discrimination using stored algorithms of gas concentrations at various points/areas in the imaged area.

Voice Communication with Ground. Voice communication with the ground will probably go on intermittently throughout each orbit. The communication sequence shown in Figure 6-1 represents a voice summary of results and findings for that pass, alerting the ground to significant findings, problems, and replanning needed.

Enter Mission Plan Changes. Mission replanning is primarily a ground responsibility. Changes which do not require ephemeris calculations, such as activating or disabling a sensor for a given pass, altering its operating parameters or selecting an alternate stored plan, can be inserted into the computer from the console keyboards.

Scheduled Tape Recorder Maintenance. All common core support equipment is located in the Sortie Lab and accessible to the as are test equipment, tools, and spare parts required for in-flight repair of those equipments critical to mission success. Daily calibration and servicing of the tape recorders is shown as a scheduled task, with some crew time reserved for unscheduled contingencies.

Figure 6-2 summarizes the division of duties between computer and crew in implementing critical system functions.

6.3 CREW SIZING FOR BASELINE MISSION

The system configuration and crew function allocations have been designed with sufficient flexibility to accommodate the baseline pollution mission and other MEO payloads without increasing the number of crew members. Aside from a few critical decision points, it is not necessary for effective system operation that the crew process or monitor all sensor data in real time. The crew can select high-priority parameters for real-time observation, with automatic algorithms and post-pass review available for more detailed evaluation. The number of consoles and the display/control equipments described in the following section have been selected with sufficient capability to support a moderate increase in crew functions.

FUNCTION	DATA MANAGEMENT SYSTEM	CREW
SIMULTANEOUS OPERATION OF MULTIPLE EXPERIMENTS IN SEVERAL DISCIPLINES	<ul style="list-style-type: none"> • AUTOMATIC PROGRAMMING OF SENSORS (OPERATION AND POINTING) BASED ON PRE-STORED TIME-LINE • STORE AND IMPLEMENT CHANGES DATA-LINKED FROM GROUND 	<ul style="list-style-type: none"> • SELECT STORED ALTERNATE EXPERIMENT IN CASE OF ADVERSE WEATHER OR SENSOR MALFUNCTION
REAL-TIME PROCESSING OF SENSOR DATA	<ul style="list-style-type: none"> • RECORD DATA ON TAPE • FORMAT CRT DISPLAYS <ul style="list-style-type: none"> • COLOR, FALSE COLOR, AND Δ DISPLAYS OF SPECTRAL BANDS • ALGORITHMS FOR EVALUATION OF SELECTED SENSOR OUTPUTS 	<ul style="list-style-type: none"> • EVALUATE DATA VALIDITY • VOICE ANNOTATION OF SENSOR DATA • SEARCH FOR TARGETS OF INTEREST • MARK INTERESTING DATA SEGMENTS FOR POST-PASS REPLAY AND ANALYSIS
POST-PASS ANALYSIS OF DATA TAPES	<ul style="list-style-type: none"> • PLAYBACK DATA TAPES • FORMAT CRT DISPLAYS • MORE COMPLEX ALGORITHMS FOR NON-REAL TIME ANALYSIS AND DISPLAY OF SENSOR OUTPUTS • TRANSMIT SELECTED FRAMES TO GROUND 	<ul style="list-style-type: none"> • CHECK INTEGRITY OF DATA TAPES • SELECT HIGH-PRIORITY DATA FRAMES FOR TRANSMISSION TO GROUND • ADDITIONAL VOICE ANNOTATION OF DATA • VOICE REPORT TO INVESTIGATORS ON GROUND
PREPARE FOR NEXT DATA-TAKING SEQUENCE	<ul style="list-style-type: none"> • DISPLAY MISSION PLAN • RETRIEVE MICROFILM BRIEFING MATERIALS FOR DISPLAY 	<ul style="list-style-type: none"> • REVIEW PLAN AND BRIEFING MATERIALS • MOUNT AND LABEL FRESH TAPE REELS

Figure 6-2. MEO Implementation of Critical System Functions

6.4 CONSOLE DESIGN

The console configuration utilizes currently-available commercial equipments designed with standard minicomputer interfaces. Three identical consoles are required, each of which accommodates two 16-inch CRT's, a microfiche reader, and a multifunction keyboard. Display/control equipment characteristics are listed in Table 6-1.

Table 6-1. Console Display/Control Equipments

CRT DISPLAYS - (2)

1000-LINE RESOLUTION
FOUR-COLOR PENETRATION PHOSPHOR
ALPHANUMERICS AND GRAPHICS
DIGITIZED VIDEO-8 GRAY LEVELS
RASTER SCAN
CONICAL SCAN
MIL SPEC DESIGN

MICROFICHE READER

STORES 73,000 PAGES
COMPUTER RETRIEVAL - 4 SECONDS MAXIMUM
STANDARD COMPUTER INTERFACE

MULTIFUNCTION KEYBOARD

FUNCTION KEYS LABELLED BY COMPUTER
SOFTWARE LOGIC TREE FOR DATA ENTRY AND DISPLAY CALL UP
CAPABILITY TO ENTER LOGIC TREE AT ANY LEVEL
MINIMUM NUMBER OF DEDICATED CONTROLS
EFFICIENT, ERROR-FREE INTERFACE

The CRT's, designed by Motorola for shipboard and airborne applications, provide for mixed display of alphanumerics and graphics, as well as raster and conical scan imagery in four colors. Each CRT can thus accommodate a high-resolution 1000-line frame of up to four spectral bands, TV imagery, or several A-scan displays of non-imaging

sensors together with an alphanumeric listing of the mission plan. The microfiche reader can at the same time sequentially display the maps, reference signatures, and other materials needed for real-time evaluation of the sensor formats selected for CRT display.

The multifunction keyboard design is well-suited for a data bus system in which all commands are transmitted through the central computer, rather than on dedicated wires. A successful application of this approach has been developed at TRW for display and control of remote sensors in the design of a regional air pollution monitoring system.

6.5 SORTIE LAB FACILITY LAYOUTS

Four different equipment configurations utilizing both standard length (20 ft) and short (10 ft) pressurized modules were developed during this study. They represent different solutions arrived at in attempting to locate consoles adjacent to the two viewing instruments. The latter must extend through the pressure vessel skin with minimal impact on structural integrity while providing unobstructed fields of view of the earth in inverted orbital flight. A preliminary concept for a crew chair assembly designed to provide mobility and minimize fatigue during extended work periods under low-g is also described here.

6.5.1 Floorless Wall-Mounted Equipment Configuration

A detailed drawing of this layout is appended to this volume in Sheet 1 of Drawing PDO-268. A simplified layout drawing is presented in Figure 6-3. The tracking telescope extends through the end dome, with the wide-angle viewer mounted on a wall hatch. Given these telescope locations, a single-level layout of consoles and equipment mounted on a Skylab-type grid floor is not possible. In addition, it is not possible to optimize viewing of the CRT displays and microfiche viewer located in the consoles for crew members using the telescope and viewer without employing an angled (wraparound) console configuration.

Our first solution was a floorless design with consoles, equipment racks and tape storage cabinets mounted to the wall on two levels. A lightweight crew chair assembly with chairs actuated by small electric motors, capable of linear vertical motion as well as rotary motion

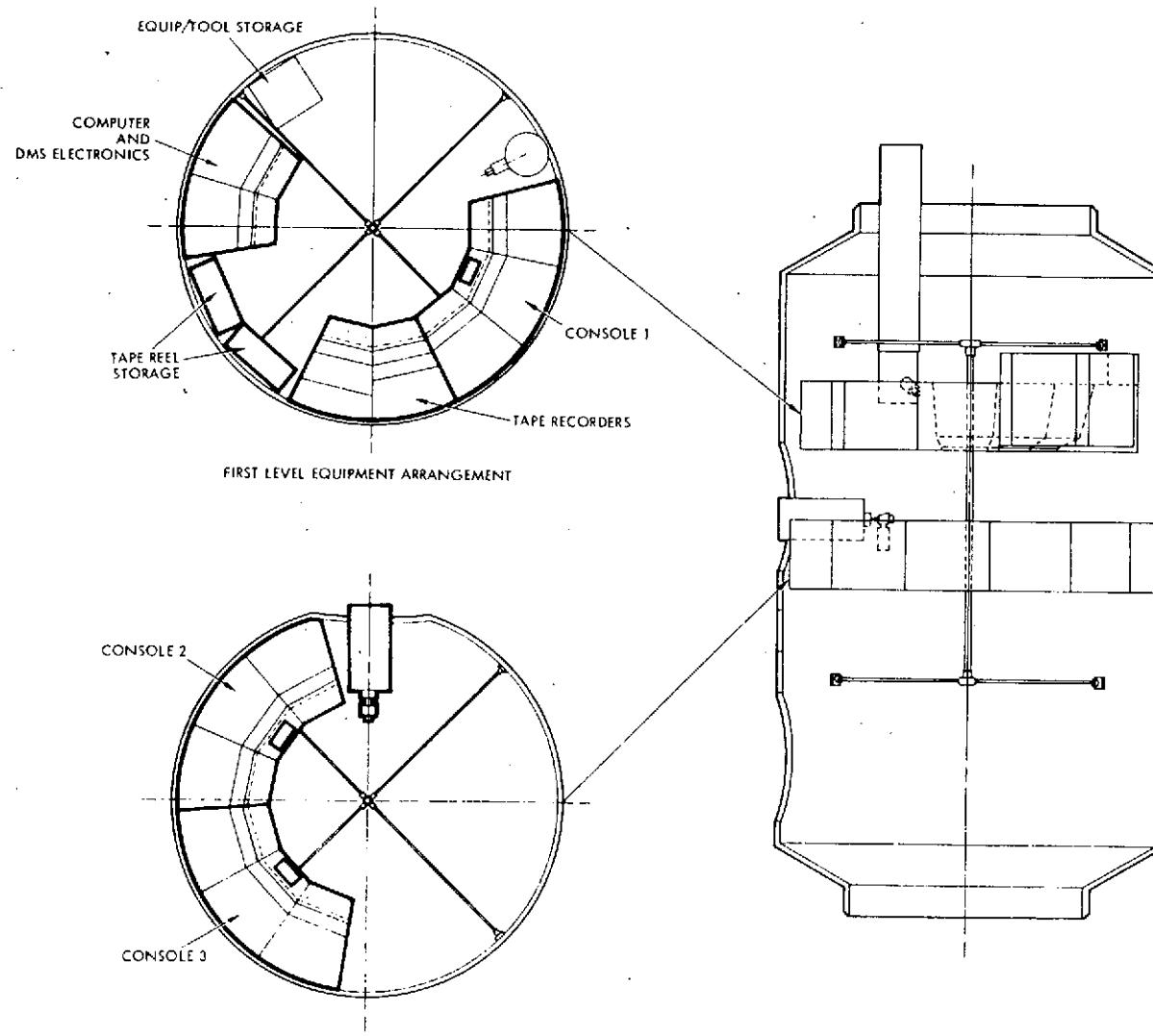


Figure 6-3. Sortie Lab Layout 1:
Floorless Wall-Mounted Configuration/Standard Module

around two vertical axes, is shown in Figure 6-4 and Sheet 2 of Drawing PDO-268.

The chair provides a belt and foot well for leg and body restraint, as well as support for operating controls and tools under low-g conditions. Chair motion controls mounted on the arms allow the operator to move from a console to equipment racks and between levels quickly and effortlessly.

The advantage of this layout is that it has structural strength with minimum weight penalty since there is direct attachment of equipment to wall structural members. A major shortcoming is that it does not meet the guideline requirement that the Sortie Lab interior be designed for a normal orientation in a horizontal position during maintenance, refurbishment, and checkout activities.

It should be noted that in this configuration there is a large amount of space available in the standard module to carry along equipment or sensors.

6.5.2 Horizontal Configuration/Short Module

A configuration meeting the above guideline requirement is shown in Figure 6-5 and Sheet 1 of Drawing PDO-270. This is a circular arrangement in which wraparound consoles and equipment racks are supported from vertical structural members above a grid floor. A modified chair assembly is utilized, since the telescope and viewer are situated too far above the standard floor level to be used by a standing crew member. It is possible to fit all equipment in the short module by placement in a two-level arrangement. The three consoles, computer, data management electronics and tape recorders are located in the upper ring, accessible to all chairs. Tape and maintenance equipment storage cabinets are located below and are accessible to two chairs under any manning condition.

6.5.3 Horizontal Configuration/Standard Module

Figure 6-6 and Sheet 2 of Drawing PDO-270 show this circular configuration located at the rear of the 20-ft module. The primary feature of this configuration is the space available for other experi-

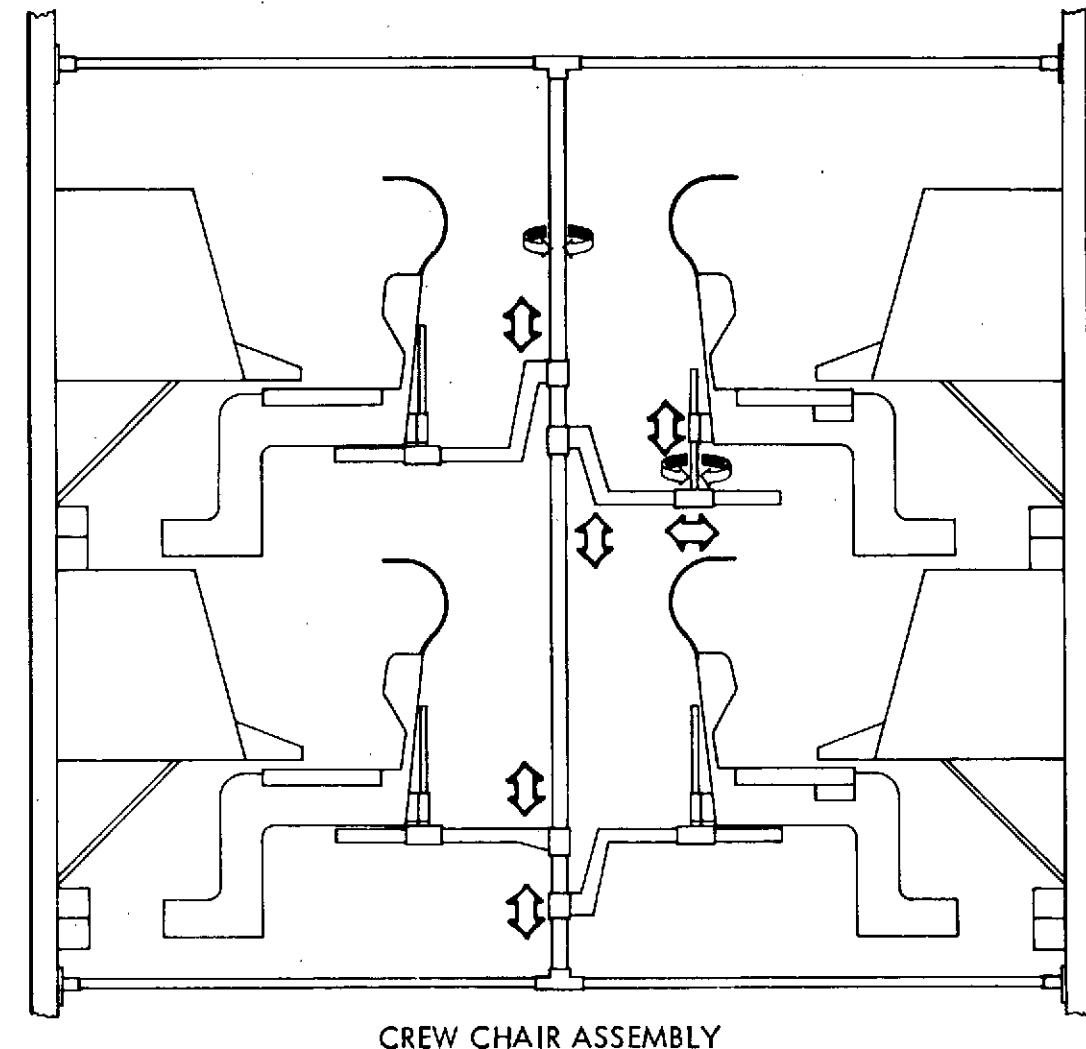
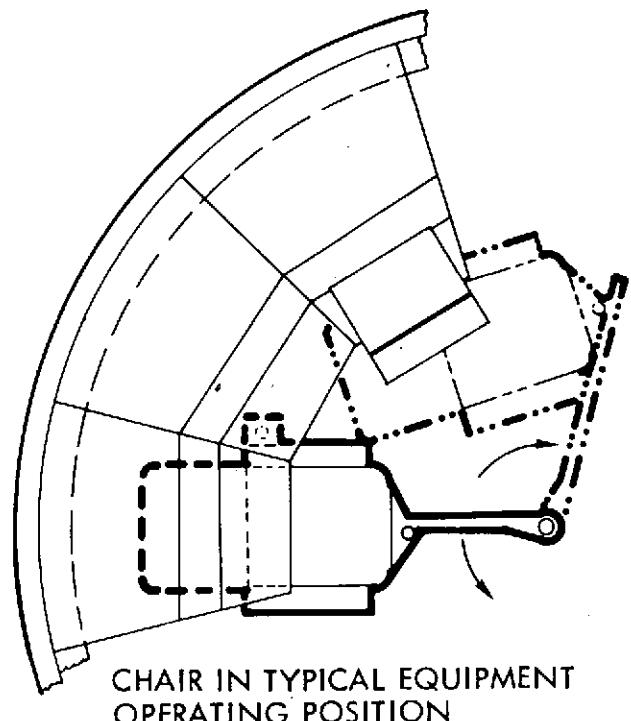


Figure 6-4. Crew Chair Assembly

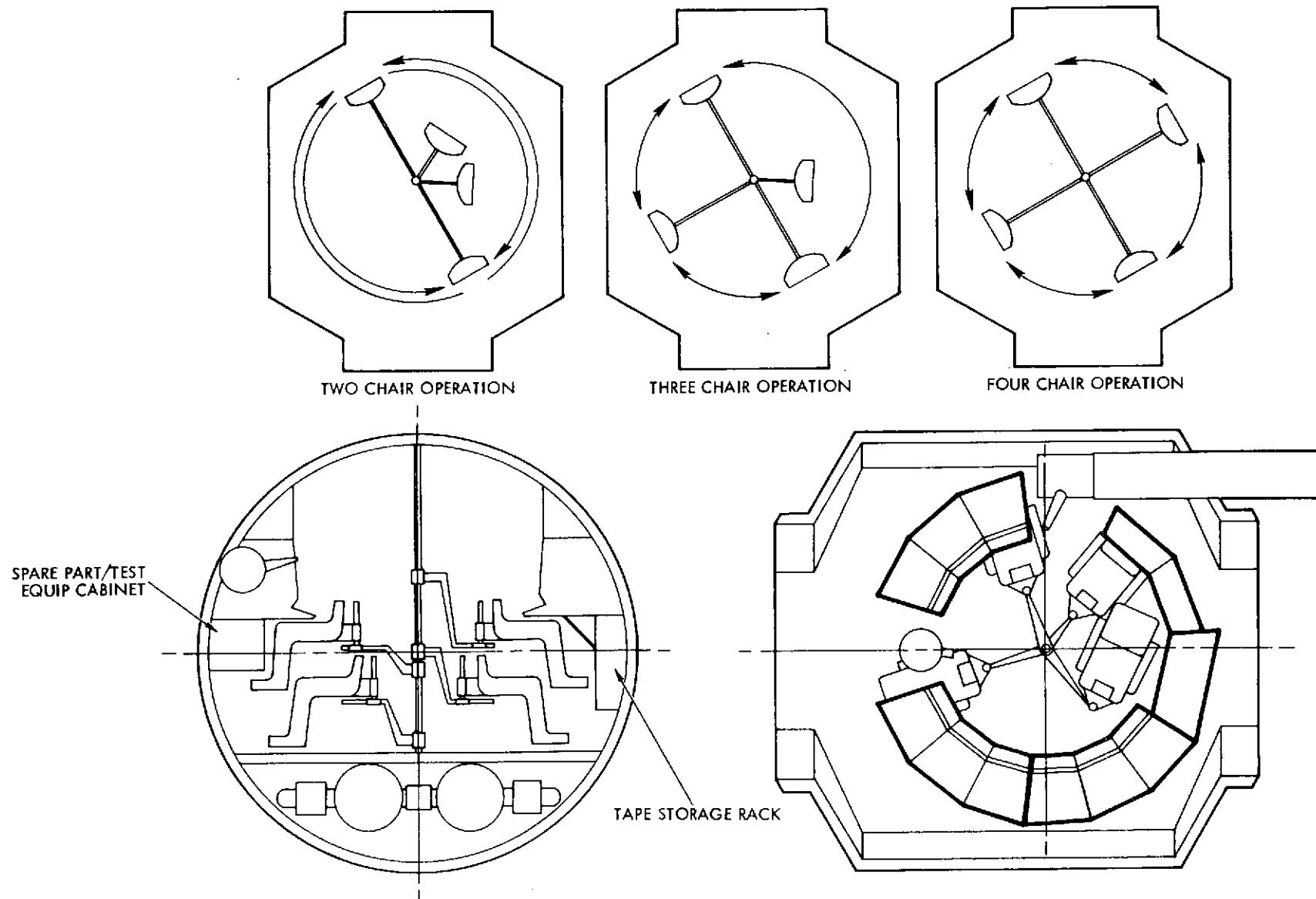


Figure 6-5. Sortie Lab Layout 2:
Floor-Mounted Circular Configuration/Short Module

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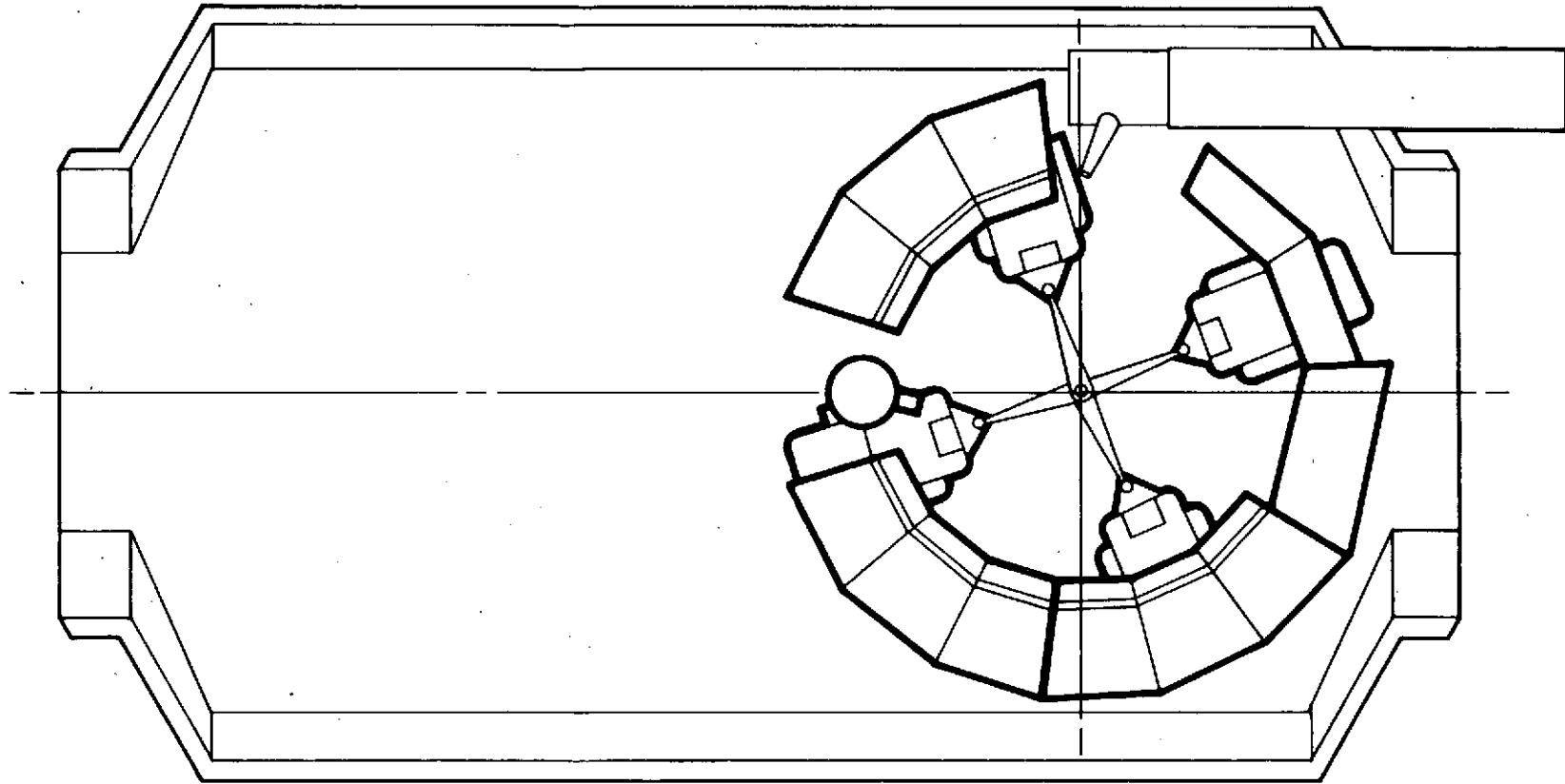


Figure 6-6. Sortie Lab Layout 3:
Floor-Mounted Circular Configuration/Standard Module

C2

ments and additional equipment, with more than one-half of the length of the module available for their accommodation.

6.5.4 Floor-Mounted Circular and Linear Configuration

A fourth layout was prepared in an attempt to use a more conventional floor-mounted console design that would not require chairs for console and telescope operation. The result, shown in Figure 6-7 and Drawing PDO-271, was not successful; it is presented here to illustrate some of the problems to be considered in further design efforts.

It was found necessary once again to use a wraparound console design, since a linear console could not be located adjacent to the telescopes for efficient joint use. Simplified chairs were employed at two consoles; use of the telescope or viewer by a standing crew member employing foot restraints would require that he stand on a pedestal, or would require extensive redesign of the telescope and viewer.

The third console is lower, so that it can be used by a standing crew member, who would use an overhead hand rail to reach the equipment racks located on the opposite wall. The layout makes for less efficient use of available space than the other configurations.

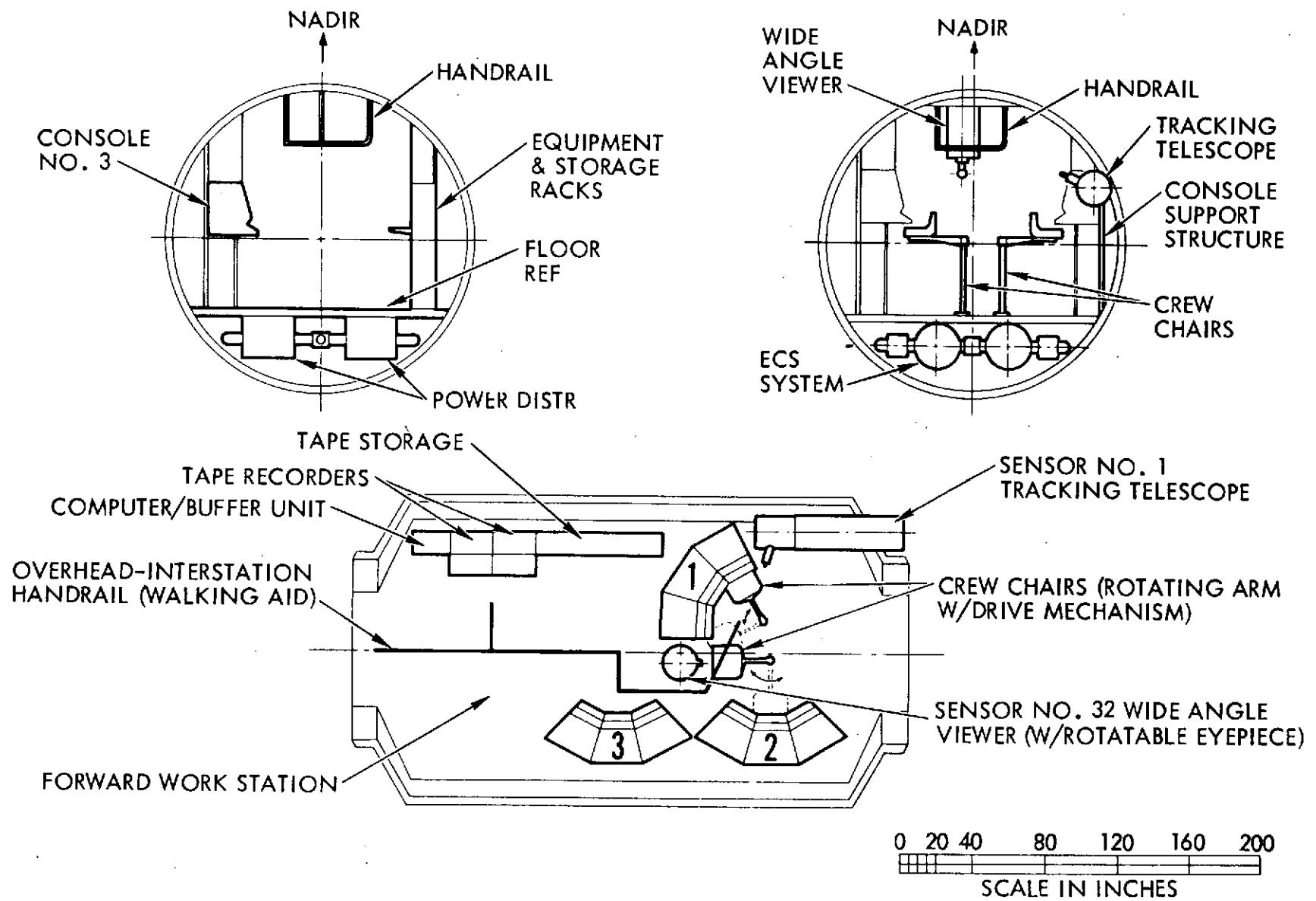


Figure 6-7. Sortie Lab Layout 4:
Floor-Mounted Circular and Linear Configuration/Standard Module

7.0 SORTIE LAB COMMON CORE EQUIPMENT

This section describes the equipments and subsystems which, together with consoles and crew accommodations, constitute the Sortie Lab Common Core Equipment.

7.1 DATA MANAGEMENT AND COMMUNICATION SUBSYSTEM

The data management and communications system design considerations were derived from the collective data and command requirements of the MEO, Sortie Laboratory and Shuttle Orbiter. The philosophy used in configuring the baseline was to obtain the maximum of worthwhile scientific instrument data within the constraints of existing technology and orbiter facilities with no further investment in additional special data reduction equipment and/or orbiter facility modification.

7.1.1 Assumptions

Communication:

- All communications to the ground will be through the Orbiter systems.
- The capability for continuous voice communication between the Sortie Lab and Shuttle Orbiter shall be provided.
- Use existing MSFN/STADAN ground stations.
- During an emergency/disaster real time telemetry data can be transmitted to ground through Orbiter communication facilities.
- A direct real-time wide-band communication system on Sortie Lab may be desirable for high data rate sensors.

Data Management:

- The Sortie Lab primary data mode shall be for onboard data recording of scientific instrument data.
- Subsystem data will be recorded on board during on-orbit operations for analysis after mission completion.
- The Sortie Lab data management system shall provide payload status information to the Orbiter and to the ground as required.

7.1.2 Data Management Alternatives

There are numerous alternate data handling paths between the Sortie Lab experiment source and the ultimate user. In the case of Sortie missions, a cost-effective choice must be made between on-board processing in the Sortie Lab and Shuttle functions.

Figure 7-1 shows several practical Sortie mission data handling alternatives.

With "man-in-the-loop", as will be the case in Sortie missions, the opportunity exists for real-time data screening and control. This is indicated in the box labelled "quick-look and observer processing." Preliminary screening of magnetic tapes for special phenomena, or evaluation of data stored in electronic memory prior to recording are scientific operator functions. These same functions may also be performed using Shuttle data management, control and display subsystems.

It is important to realize that reduction of data quantities as near the source as possible is an important goal in minimizing overall data handling cost. Much of the cost of an experimental program involves editing, searching, archiving, reformatting, extraction and duplication during ground processing. By editing, maintaining quality control during recording, formatting, and combining housekeeping data with sensor outputs on board the Sortie Lab, significant cost reduction may result. Indeed, one of the major arguments for man's presence is his ability to increase the amount of useful information (as opposed to raw data) gathered by the Sortie Lab.

7.1.3 Data Management Subsystem

Baseline Data Management Configuration

The baseline data management configuration shown in Figure 7-2 contains all the equipment required to manage the flow of data to and from all instrument sensors and support systems. This includes the receipt, processing and execution of real-time and stored commands; the processing and formatting of instrumentation data for tape recorder storage and for transmission to the ground stations via orbiter communication facilities; and the processing, formatting, storage and forwarding for transmission of all diagnostic and status information from all MEO systems and subsystems.

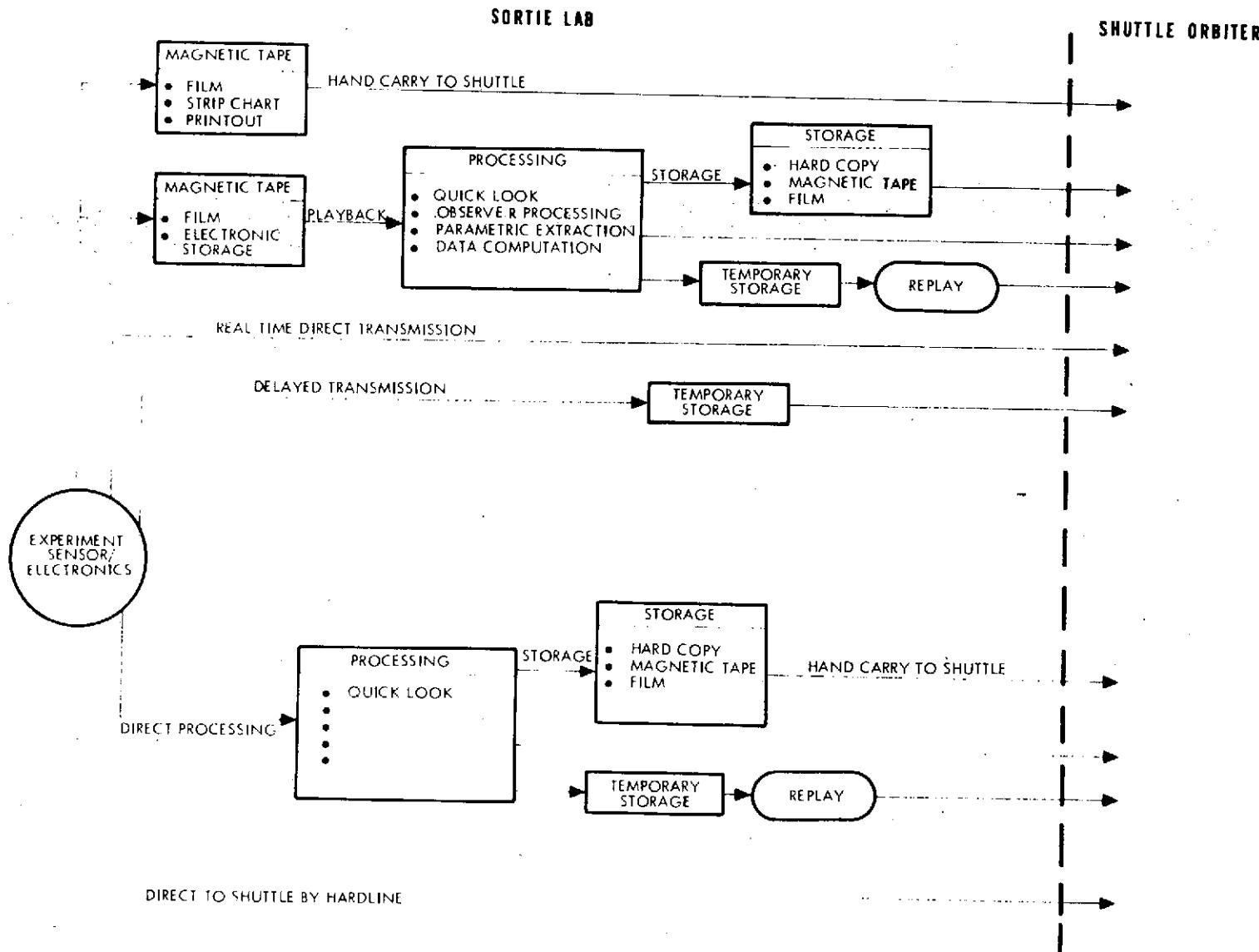


Figure 7-1. Sortie Mission Data Handling Alternatives

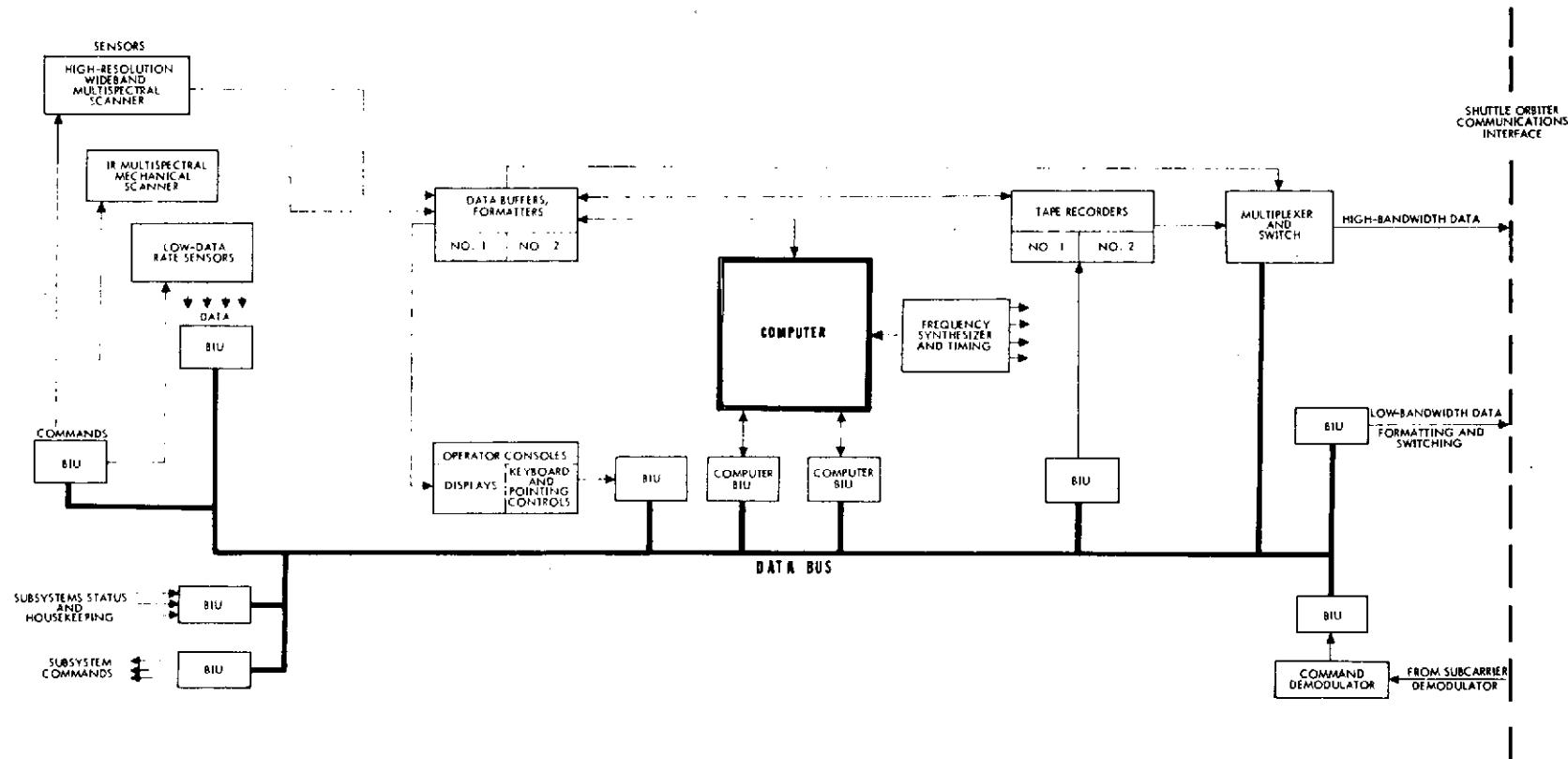


Figure 7-2. Data Management System

The data management subsystem performs the following major functions:

- Processing and storage of instrument sensor data.
- Processing and storage of engineering (spacecraft health and status) data.
- All on-board digital computing and preliminary analysis as required.
- On-board command control and sequencing.

The greatest bulk of MEO data consists of wide-band digital multispectral sensor data. Because of the data rates, these sources require special data buffer and formatter systems. The basic data handling approach for these data is on-board storage in tape recorders. Data are recorded with volumes ranging from 2×10^7 to 3×10^{12} bits/mission. Transmission of multispectral data to ground via Shuttle Orbiter has limited applicability due to the limited data handling capacity of MSFN on a per day basis.

Except for multispectral sensor, most sensor data is processed through bus interface units (BIUs) to the data bus system. Also, the secondary data for control and housekeeping is transmitted over a time multiplexed, data bus system. The BIUs are used to connect the bus to those subsystems monitored and controlled by the on-board computer.

The data bus concept (Figure 7-3) involves the use of one or two conductors connected to a number of terminals distributed throughout the Sortie Lab structure. These terminals act as local data acquisition and command distribution points for devices connected to them. Each terminal is uniquely addressable and performs multiplexing/demultiplexing under command control. In this scheme, the majority of functions required in a centralized I/O unit for the hardwired interfaces are distributed among the terminals.

The BIUs perform the following functions:

- a) Provide a means for each instrument sensor and subsystem to receive/transmit information on the bus
- b) Decode computer instructions into functional commands for sensors or subsystems

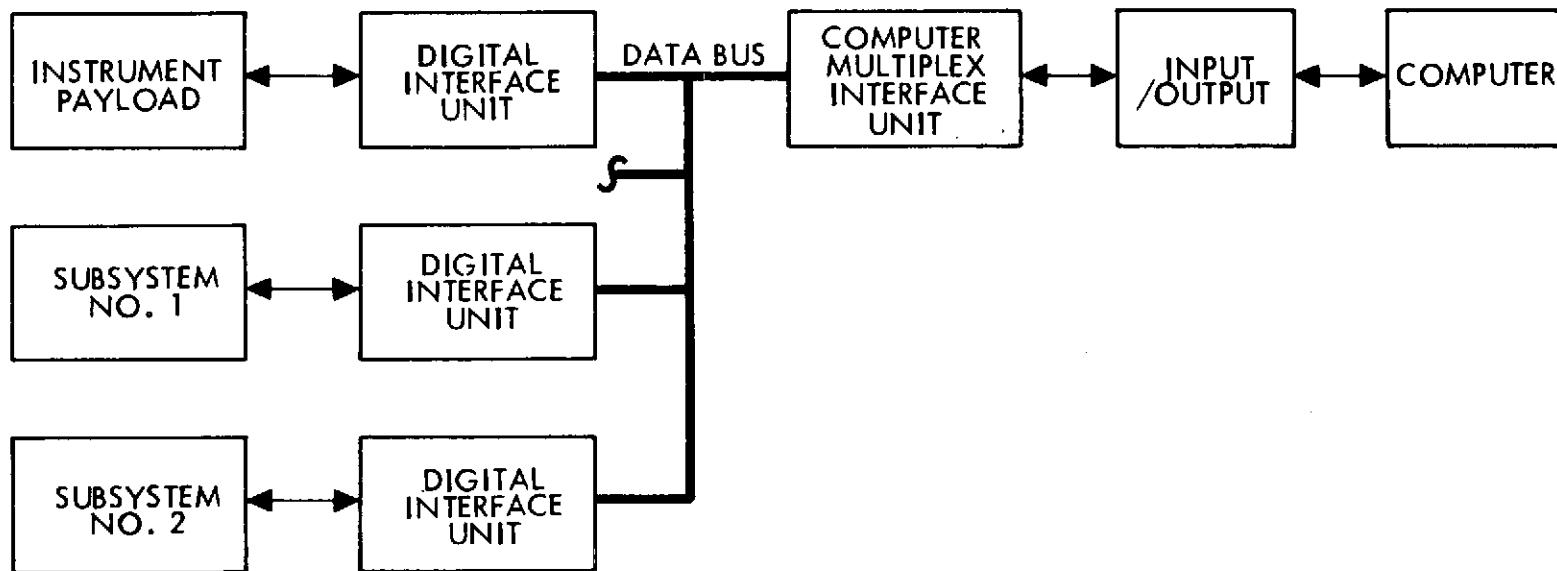


Figure 7-3. Data Bus System

- c) Provide a buffer for data generated by the instrument sensors or subsystem
- d) Provide a buffer for data and instructions sent to the instrument controllers

The BIU contains the following:

- Bus drivers/receivers for driving and receiving information on the bus
- A data buffer for storing low rate data, device status and control commands sent to the instrument sensor equipment
- An experiment controller for decoding and executing the control commands sent to the sensor equipment.

The computer is required to interface with the data bus. Buffer interface units similar to BIUs are used for the computer interface. These special interface units perform the following functions:

- Provide timing and control of the data bus
- Provide data buffering and word formatting
- Provide error detection for the data bus
- Handle status and interrupt information from the subsystem to the computer
- Multiplex and demultiplex data.

Onboard Storage

The magnetic tape recorder has been selected for the majority of spacecraft bulk data storage applications where optimum size, weight, power, cost and reliability tradeoffs have been considered, and a random access memory is not required. Where data storage over 10^7 bits is required in a serial format, no other candidate memory system currently available compares favorably with the tape recorder. Considerable effort is currently in progress to replace the electromechanical nature of a tape recorder with an all solid-state memory. Some of this effort appears promising, but is admittedly many years away from flight operational status. A review of NASA programs in the 1973-80 period indicates that where hardware dollars have actually been committed for flight hardware, the magnetic tape recorder is still being selected for

those applications requiring 10^7 bits (non-random access) or greater data capacity. Table 7-1 summarizes the tape recorder technology.

Table 7-1. Summary of Tape Recorder Technology

Present Status	Projected Status (Pre-1980)	More Development Needed in
<u>Longitudinal</u> 25K bpi/T (Manchester) 10^9 bits capacity 28 tracks on one-inch tape Weight: 49 pounds Power: 50 watts Bandwidth: 56 Mbps	50 K bpi/T (Manchester) 10^{11} to 10^{13} bits capacity 100 tracks on two-inch tape Weight: 25 pounds Power: 20 watts Bandwidth: 100 Mbps	<ul style="list-style-type: none"> Utilization of double density and other coding methods Increased mechanical reliability

The general parameters of a tape recorder to fulfill the Sortie Lab data requirements are as follows:

- Read in Rate 100 Mbps
- Storage Capacity/Mission 3×10^{12} bits

The recorder systems considered and their parameters are listed in Table 7-2, along with the recommended tape recorder.

RCA, under NASA funding, is currently examining the feasibility of recording on 100 tracks operating on one Mbps (100 Mbps on a single recorder), Reference 7-1. The transport used in this demonstration is a longitudinal version of the recorder used on the ERTS program and 25,000 bpi linear packing density is predicted using double density coding (delay modulation), and deskew buffers to time-align all 100 channels during playback. The expected error rate is approximately 1 in 10^5 , the signal-to-noise ratio (wideband) is 30 db (pp/rms) and the skew across the two-inch tape is less than 30 microinches.

Redundant recorders are used for system reliability, as well as to permit simultaneous data recording and data-link transmission of selected data to the ground. A data buffer/formatter is required for buffering of data received from the High Resolution Wideband Multispectral Scanner at 200 Mbps on a 33 percent duty cycle. Two data buffer formatters, shown in Figure 7-2, are used for this function as well as display refresh buffering during data acquisition and replay.

Table 7-2. Comparison of Near-Term Magnetic Tape Transports

Contractor/ Model	RCA/ERTS* (IRAD)	Ampex/ AR 700	Ampex/ AR 1700	Leach MTR 7000	Borg-Warner PERT	HEAO (Proposed)
Number of tracks	100	28	28	12	30	3
Recorder operation	Longitudinal	Longitudinal	Longitudinal	Longitudinal	Longitudinal Newell drive	Longitudinal
Tape speed (ips)	40	60	120	120	Up to 1000	Record 1.54 Playback 28
Tape length (feet)	2000	7200	9200	9200	2400	2100
Tape width (inches)	2	1	1	1	1/2	1/4
Bandwidth (mb/sec/T)	1	1.0	2.0	2.0	6-15	Record 25.6 kbps Playback 512 kbps
Packing density (kb/I/T)	25	20	20	16.7	15	5.94
Weight (lbs)	74	48	27	100	50	15
Size (cu ft)	2.3	1.3	1.5	3.7	1.0	600 cu in.
Power (watts)	90	175	220	700	150	2.5 (max.)
Signal/noise (db)	30	20	20	22	24	45
Data capacity (bits)	8×10^{10}	4.8×10^9	6.2×10^{10}	2.2×10^{10}	1.3×10^9	4.5×10^8
Availability	In development	Used on Skylab program	In production not space qualified	Wright- Patterson AFB	In development	In development
Estimated ROM cost	180K per flight unit 800K develop- ment costs	120K per flight unit 650K for development	120K per flight unit 650K for development	60K per flight unit 600K for development	160K per flight unit 800K for development	60K per flight unit 400K for development

* Recommended Recorder

Operations Control Computer

This computer is the nerve center of operations aboard the Sortie Lab. The Sortie Lab utilizes a computer system and associated software to provide the control functions to various subsystems. The computer communicates with the subsystems via the data bus which carries status information and control commands. The computer employs command information, onboard sensor units, and preprogrammed computational algorithms to provide the required command and control outputs. Figure 7-4 shows a block diagram of the system implementation.

In general, there are three approaches for data processing. These alternatives are:

- 1) Mission-dedicated Sortie Lab computer
- 2) Computer distributed between Sortie Lab and Orbiter
- 3) Shuttle Orbiter shared computer.

These alternatives are traded in Table 7-3. From the tradeoff it is concluded that the mission dedicated alternative (i. e., autonomous computer) is the most cost effective and this is recommended for the MEO system.

Functions — The following are some of the important functions required to be performed by the Sortie Lab computer:

- Command interpretation and execution
- Attitude and pointing program control and computation
- Communications to and from the Shuttle Orbiter. This includes sending real-time telemetry when requested and receiving commands
- Monitoring the health of vehicle systems and executing systems checkout. Malfunction detection and redundancy management are required
- Sequencing operations. The data management portion of the computer has access to the time clock and initiates sequences of action at appropriate times.

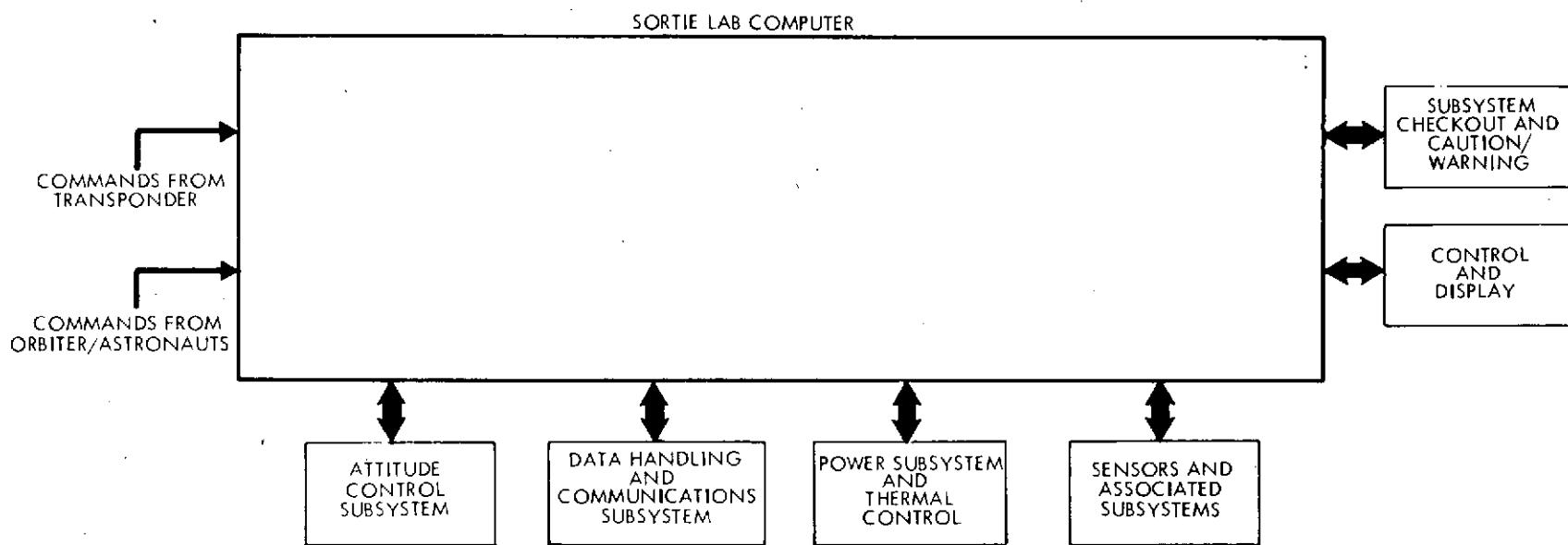


Figure 7-4. Sortie Lab Command and Control Computer System

Table 7-3. Data Processing (Computer) Alternative Trades

Trade Parameter	Computer Location		
	Mission-Dedicated Sortie Lab	Distributed between Sortie Lab and Orbiter	Orbiter Shared
PERFORMANCE REQUIREMENTS	Met with small computer	Functions that vary mission-to-mission performed on Sortie Lab computer. Stable requirements handled using orbiter computer.	<ul style="list-style-type: none"> • Adequate capability • Interface may be a limitation.
HARDWARE COST	<ul style="list-style-type: none"> • Least expensive • Medium capability computer • Discipline oriented. 	<ul style="list-style-type: none"> • Small computers plus Sortie Lab/Orbiter interface equipment. 	<ul style="list-style-type: none"> • Most expensive • Complex hardware • Interface changes each mission.
SOFTWARE COST	<ul style="list-style-type: none"> • Least expensive <ul style="list-style-type: none"> — Mission dedicated discipline oriented computer software less costly to modify because the evolutionary nature of a specific payload requires minimum changes. 	<ul style="list-style-type: none"> • Requires reprogramming Mission dedicated software plus interface control software each mission 	<ul style="list-style-type: none"> • Most expensive <ul style="list-style-type: none"> — Requires reprogramming entire processor each mission.

Requirements — Memory and processing time estimates for monitor, command and control of various subsystems, the data bus and data formatting, and the instrument sensors are summarized in Table 7-4. These ROM estimates are obtained after an evaluation of functional requirements. A 2 μ sec execute time was used. One second was used for the basic computer cycle time. Twenty-five percent of instructions were assumed to be long instructions requiring five times as much time as the short instructions.

Total estimated requirements for the operational computer are 14550 words storage and 235.1 milliseconds operations time based on a 2 μ sec short instruction.

These studies indicate that a small computer of 16K word memory with an average "add" execution time of 2 μ sec will be adequate.

Table 7-5 provides a list of candidate computers.

Recommended Computer — A computer with the modular capacity and capability of the CDC-469 MOS/LSI computer seems adequate to meet those requirements and future growth. It has the desirable feature of low weight, low power, and high speed. The memory capacity is expandable to 65.5 K x 16 bits. An acceptable unit in 1975-80 may differ in detail, but a conservative system design can be made assuming the use of the CDC unit.

7.1.4 Communication Subsystem

The real-time information transmission and reception capabilities required to support the Sortie Laboratory are quite minimal. Sortie Lab makes maximum use of available Shuttle communication capability. This simplifies the MEO onboard system and realizes savings in cost, weight and power at very little in cost to the Shuttle.

A summary of communication system interfaces between Sortie Lab and Shuttle Orbiter is given in Table 7-6.

Figure 7-5 shows a simplified S-band communication system via Shuttle Orbiter.

Table 7-4. Estimate of Sortie Lab Processing Requirements

Function	Memory Size (Words)	Processing Time (msec)
<u>Subsystem</u>		
a. Thermal Control	300	0.5
b. Electric Power	300	0.5
c. Communication/Data Management	1200	25.0
d. Control and Display	3600	55.0
e. Subsystem Checkout	350	5.0
f. Caution/Warning	300	3.5
g. Attitude Determination	<u>2300</u>	<u>54.0</u>
	8350	143.5
<u>Instruments</u>		
a. High Resolution Multispectral Camera	250	0.3
b. Wideband Multispectral Scanner	500	10.0
c. Multiresolution Framing Camera	150	0.3
d. Tracking Telescope	150	0.3
e. IR Multispectral Scanner	150	0.3
f. Imaging Spectrometer	150	0.3
g. Visible Radiation Polarization	150	0.3
h. Pointable Identification Camera	200	5.0
i. Air Pollution Correlation Spectrometer	150	0.3
j. High Speed Interferometer	150	0.3
k. Carbon Monoxide Pollution Experiment	150	0.3
l. Remote Gas Filter Correlation Analyzer	150	0.3
m. Radiometer	150	0.3
n. Alpha Line Viewer	150	0.3
o. Sensor Pointing Control	<u>300</u>	<u>4.0</u>
	2900	22.6
<u>Data Bus and Data Formatting</u>		
a. Command Processing	1100	21.0
b. Reconfiguration	650	7.0
c. Tape Recorder Control	400	13.0
d. Device Switching	250	6.0
e. Communication Processing	300	5.0
f. Orbiter Interface Control	<u>600</u>	<u>17.0</u>
DATA BUS	3300	69.0
INSTRUMENTS	2900	22.6
SUBSYSTEMS	<u>8350</u>	<u>143.5</u>
TOTAL	14,550 (words)	235.1 (msec)

Table 7-5. Partial List of Candidate Computers for Spaceborne Applications

Company/Computer	Status	Add/Mult. Time (μ S)	Memory (Type)	Weight in lbs	Power in Watts	Word Length in Bits	No. of Instr.	MTBF
CDC 469*	469 (Prototype)	2.4/-	16K(P. W.)	10	20	16	--	--
Autonetics	Prototype July 1972	2.5/13.75	2K (MOS)	15	20	16	68	--
BR-1018	One unit delivered	5/33	12K (P. W.)	10.5	45	18	58	--
Delco	-	4.5/73	2K ROM (N MOS) 1K RAM (N MOS)	6.2	12.5	16	32	--
G. E. CP-24	-	2.0/-	8K (Wire)	20	20	24	53	--
Honeywell 402	Modified for Viking	8.5/83	2K (ROM) .5K (Wire)	25	21	24	47	--
Honeywell 602	Shuttle engine controller	2/9	12K-16 (PW)	14	65	16	87	2700
IBM-API	In pilot production	1.4/6	8K-32 (CORE)	34	200	16/32	95	2000
IBM-SPO	In pilot production	3.5/11	12K (CORE)	20	110	16	30	2700
Raytheon-261	In final development	2.0/5.7	8K (CORE 1 μ sec)	20	150	16	42	--
Sperry FSD RMM-1	Dev.	.35/1.0	8K (P. W.)	20	100	16	64	--
Westinghouse/HDP	1 July 1972	3/8	12K (I. C.)	12	80	16	38	2000

* Recommended Computer

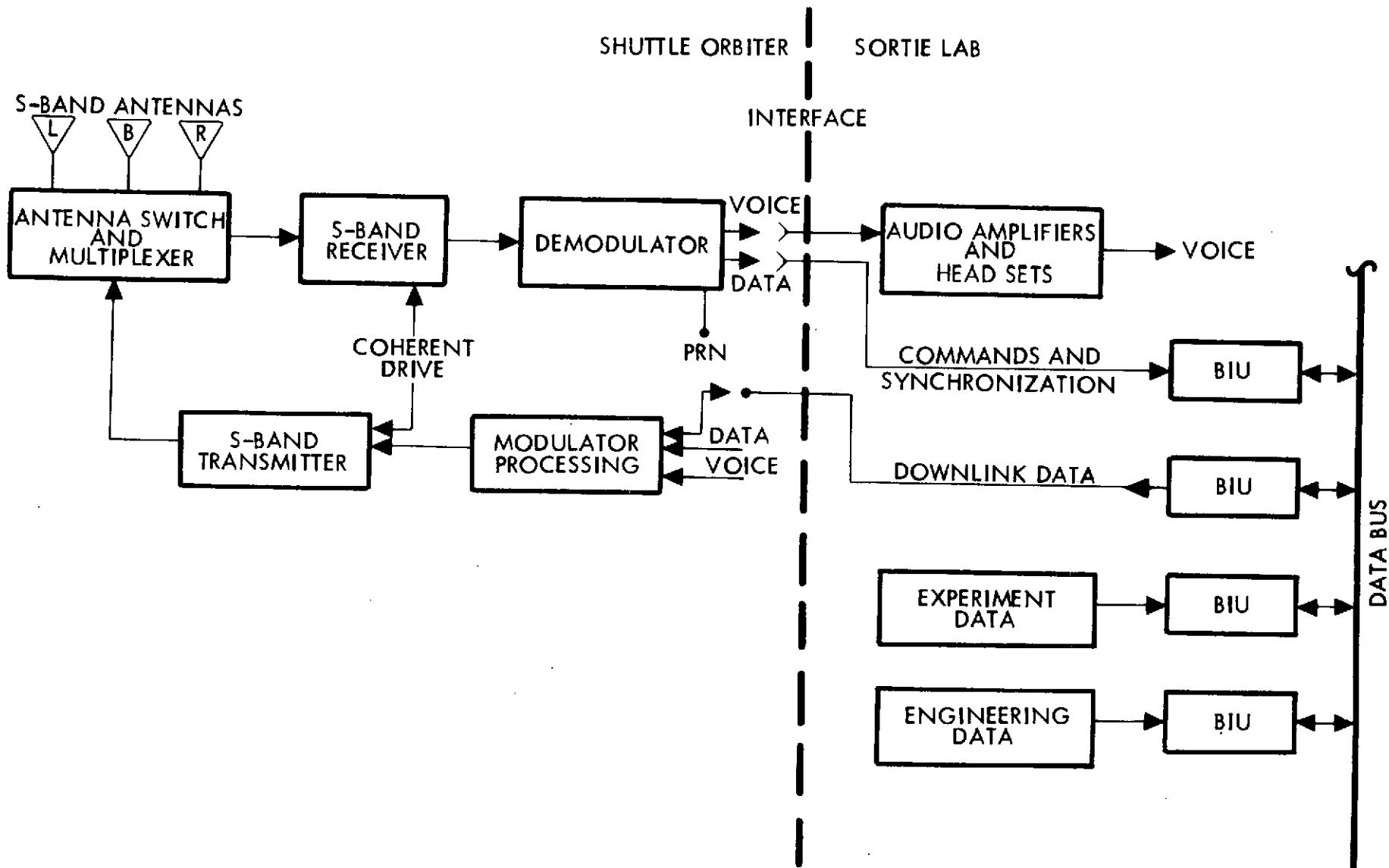


Figure 7-5. Sortie Lab Communications System
S-Band MSFN via Orbiter

Table 7-6. Communication System for Sortie Mission via Orbiter

<p>S-Band MSFN (less than 13 percent coverage)</p> <ul style="list-style-type: none"> • One full duplex voice channel using Shuttle S-band voice link (shared with Shuttle) • Command link for payloads using Shuttle S-band command link (shared with Shuttle) • Realtime S-band telemetry link for payload (subsystem and experiment) from Sortie Lab to MSFN via Shuttle Orbiter

As the experiment program evolves into more complex Sortie Lab operations, the baseline orbiter communications system capability may be exceeded. The capability to transmit wideband video or high rate digital data directly to the ground could be provided by incorporating a hardwired RF interface between the attached laboratory and the orbiter antenna system as shown in Figure 7-6. This will require the addition of an S-band wideband transmitter within the laboratory, coaxial cables, and an access port in the orbiter S-band multiplexer. These changes would have minimal effect on the baseline orbiter RF system.

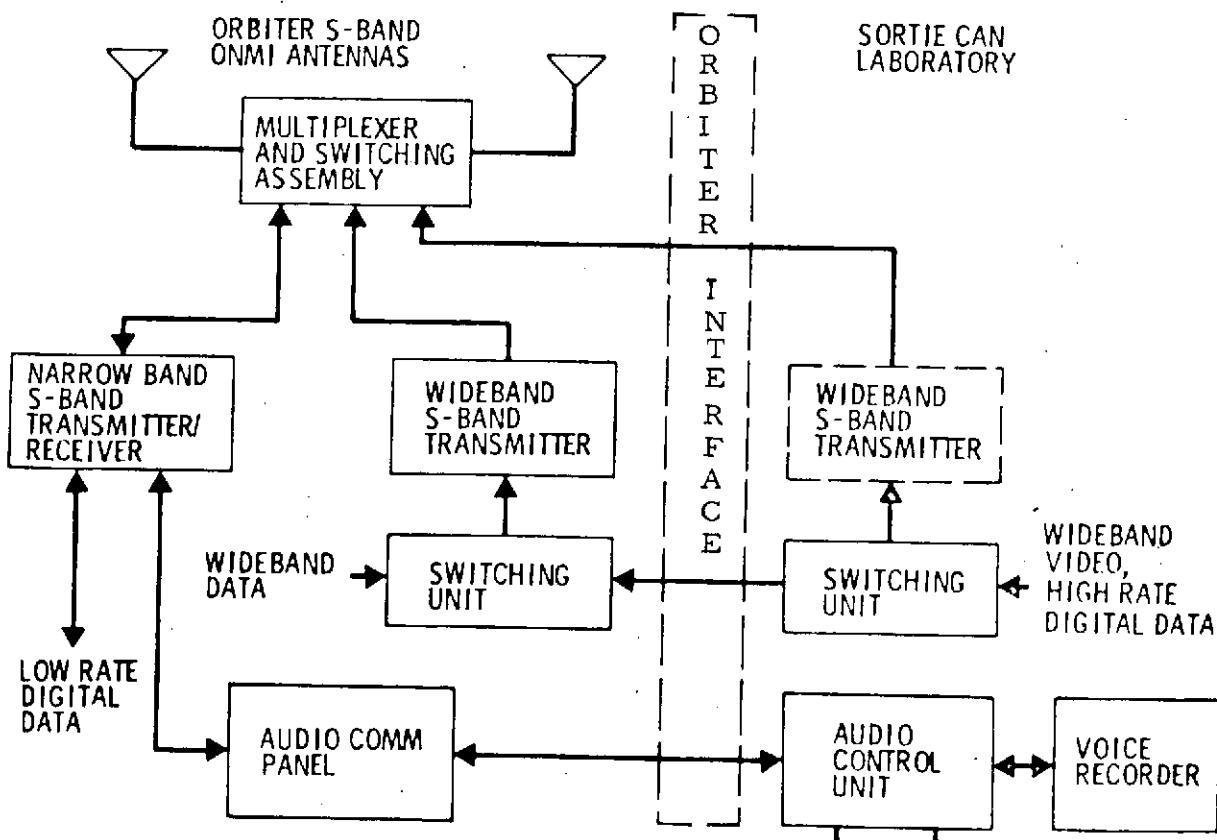


Figure 7-6. Orbiter/Sortie Communication Interface

7.1.5 Data Management Equipment Summary

An equipment summary of the data management system including the computer is presented in Table 7-7.

Table 7-7. Equipment Summary of Data Management Subsystem

Qty	Item	Weight lbs.	Volume (ft ³)	Power (Avg.)
1	Computer	20	0.3	20
2	Computer Buffer Interface Unit	2	0.2	2
10	Bus Interface Unit (BIU)	8	0.3	6
2	Command Decoder	2	0.1	1
2	Tape Recorder	75	2.5	180
2	Buffer and Data Formatter	15	1.0	5
1	Multiplexer and Switching Unit	10	0.2	5
1	Frequency Synthesizer and Timer	5	0.1	5

7.2 ELECTRIC POWER SUBSYSTEM

7.2.1 Low Cost Mission

7.2.1.1 Design Requirements

The Sortie Electric Power Subsystem (EPS) is required to generate condition, control, and distribute the power required to operate 16 sensors, data management equipment, display and controls, environmental and thermal control, and lighting. A typical six-hour power and energy load profile for the low cost mission is shown in Figure 7-7. These requirements include the EPS losses for power conditioning and distribution. The 24-hour average power level is 4.2 KW. Average power during the active experimentation period of 16.6 hours per day is 5.8 KW.

The Sortie electrical energy requirement for the most active day is 100 KW-hr with a total mission energy requirement of 500 KW-hr. Table 7-7 lists the peak power by voltage and regulation requirements for each load component. The highest peak load is 8.6 KW for two minutes, including 0.95 KW of power conditioning and distribution loss. Heating and most data management requirements are assumed to be satisfied with 28 vdc ± 15 percent. Display and control components are for the most part commercial designs and therefore, are assumed to require 115vac, 1 \emptyset , 60 Hz power regulated to ± 5 percent. Pumps, fans and interior lighting are proven aerospace designs and are assumed to require 115/200 vac, 3 \emptyset , 400 Hz power with ± 5 percent regulation. Experiment loads were not defined to the level of specifying power forms. Several are derived from existing spacecraft programs. It was, therefore, assumed that the experimentation requirements would be satisfied with 28 vdc ± 5 percent power.

The minimum emergency power requirements for the Sortie are as tabulated in Table 7-8. These loads would be required if the Sortie prime power source fails.

7.2.1.2 Preliminary Design

Power Generation. The primary power source is specified as a single fuel cell of the type and capacity to be developed for the Shuttle program. Specified fuel-cell characteristics are 7KW average power output and peaking capability of 10KW for six minutes. The fuel cell output is 30vdc $^{+2v}_{-6v}$ (28vdc ± 15 percent). This fuel cell power is adequate to supply the 5.8KW average and 8.6KW two minute peak Sortie requirement.

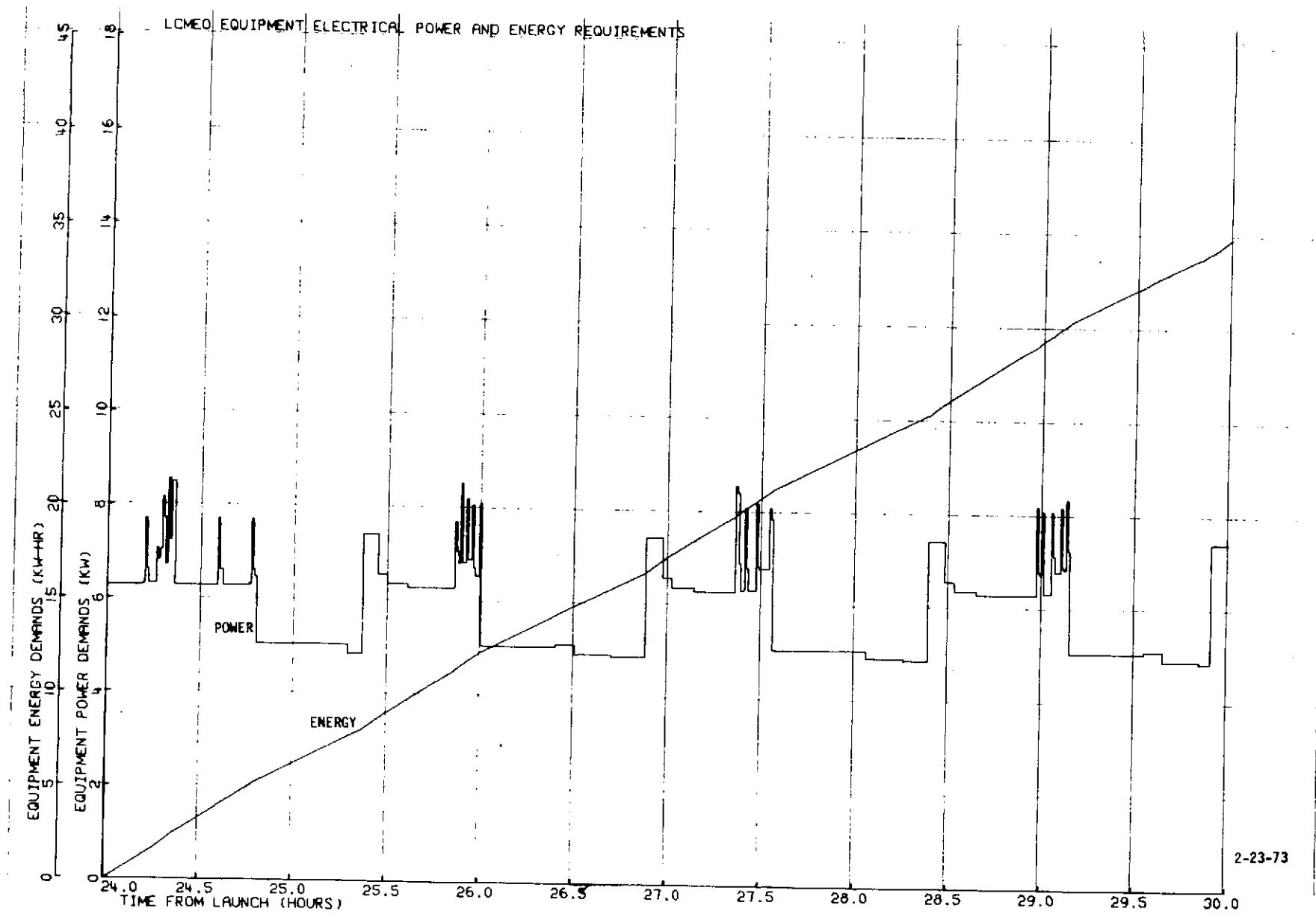


Figure 7-7. Low-Cost MEO Equipment Electrical Power and Energy Requirements

Table 7-7. Peak Power Requirements (Watts)
Low Cost System

Subsystem	28 Vdc +15%	28 Vdc +5%	115/200 Vac 400 Hz, 3Ø	115 Vac 60 Hz, 1Ø
Experiment Sensors		3720		
Thermal Control	75		225	
Environmental Control			240	
Data Management				
Computer BIU	6			
BIU's	28			
Computer				20
Command Decoder	2			
Frequency Synthesis Timer	8			
Buffer and Data Formatter	31			
Voice Annotation Recorder				10
Tape Recorder		180		
Transmitter	50			
Multiplexer	6			
Display and Control				
Console				2100
Microfilm Reader				600
Test Equipment				30
Attitude Determination				
Star Tracker	8			
Gyro Reference	12			
Sensor Electronics	19			
Lighting			200	
Crew Chairs	80			
Peak Power Requirement	325	3900	665	2760

Table 7-8. Emergency Loads (Watts)

Function	28 Vdc <u>±15%</u>	115/200 Vac 400 Hz, 3Ø
Thermal Control	75	225
Environmental Control	-	240
Lighting	50	-
Input to Inverter	547	
TOTAL	672	465*

*Inverter Output

Reactants are stored in cryogenic tanks mounted on the conical ends of the Sortie Lab. The recommended Sortie configuration permits the use of 33 inch diameter tanks. One liquid oxygen and two liquid hydrogen tanks of this size can provide the required energy of 500KW-hr with a total energy capacity of 680KW-hr.

Distribution, Conditioning and Control. Figure 7-8 is a block diagram of the Sortie EPS. Power is distributed through a main bus and two essential (emergency) buses. The main bus powers all normal payload operations including an experiment bus. Essential buses supply environmental and thermal control equipment and Sortie can lighting. The two essential buses are fed separately from the source bus and may in the event of fuel cell or feeder failures be powered from the Shuttle. Available Shuttle power of 1KW and 50KW-hr is more than adequate to supply essential loads.

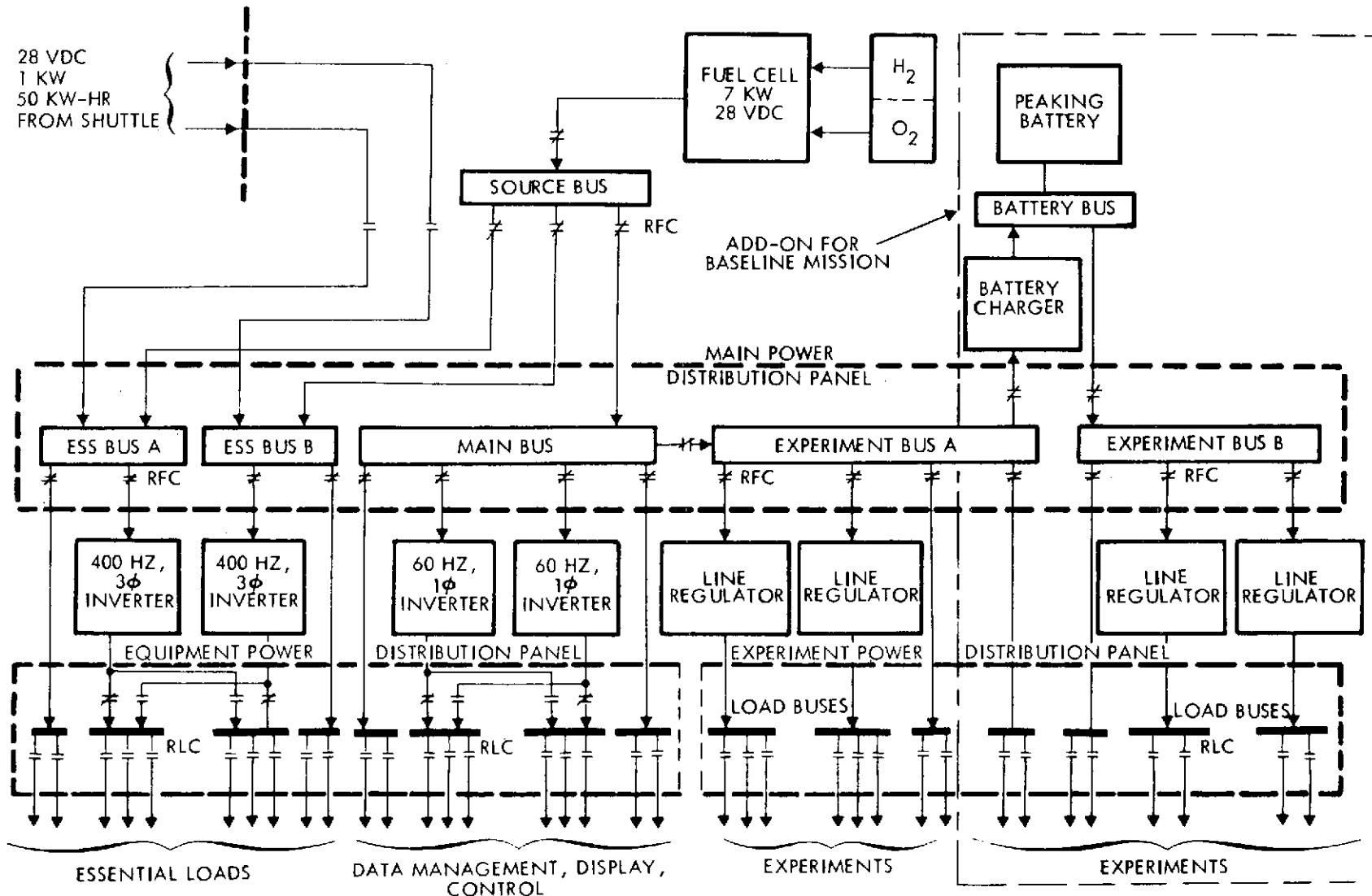
Electrical monitoring and logic circuits are provided for bus and feeder fault protection, status display and mode selection. Primary feeder switching is performed with remote controlled bus contactors located in the Main Power Distribution Panel (under the floor assembly). Load circuits are protected and controlled by remote operated circuit breakers. For equipment within the Sortie can, these load circuit breakers are located in the Equipment Power Distribution Panel (also under floor assembly). Experiment circuit breakers are located in the Experiment Power Distribution Panel (on pallet).

A generally centralized power conditioning concept is used consisting of dc voltage regulation and dc-to-ac conversion. Past studies have shown that centralized power subsystems are lighter, more efficient, lower cost, and have greater flexibility than those with only localized power conditioning. Local power conditioning within the load equipment, however, is assumed for non-standard power characteristics.

The basic EPS components and their characteristics are listed in Table 7-9.

7.2.2 Baseline Mission

7.2.2.1 Design Requirements. The baseline Sortie requirements are similar to the low cost system. The significant difference is the addition of 13 experiment sensors with an added peak load of 6,286 watts. A typical



RFC: REMOTE FEEDER CONTROL RELAY

RLC: REMOTE LOAD CONTROL RELAY

Figure 7-8. Electric Power Subsystem Block Diagram

Table 7-9. EPS Equipment List

Component	Characteristics	Per Unit			Low Cost Mission				Baseline Mission			
		Weight (lbs)	Volume (ft ³)	Cost (\$000) Non rec-rec	Quantity per System	Weight (lbs)	Volume (ft ³)	Cost (\$000) Non rec-rec	Quantity per System	Weight (lbs)	Volume (ft ³)	Cost (\$000) Non rec-rec
Fuel Cell	7 KW avg., 10 KW pk (6 min), 30 vdc	245	2.8	0-200	1	245	2.8	0-200	1	245	2.8	0-200
Reactant H ₂ and O ₂	Cryogenic storage	0.9/Kwh	-	Minor	500 Kwh	450	-	-	650 Kwh	576	-	Minor
Reactant Tankage	Shuttle O ₂ tanks, 33" dia, 32 lb H ₂ or 520 lb O ₂	133	10.9	0-100	3	399	32.7	0-300	3	399	32.7	0-300
Battery	Ag Zn, 30 vdc, 70 A-hr, 22 cells	69	0.5	60-20					1	69	0.5	60-20
Battery Charger	PWM boost regulator with current limit	13	0.5	150-25					1	13	0.5	150-25
Battery Control	Charge/discharge logic circuits and discharge relay	5	0.2	30-10					1	5	0.2	30-10
Inverter + 400 Hz	30, 115/200 vac $\pm 5\%$, 500 VA, sq. wave	14	0.5	200-20	2	28	1.0	200-40	2	28	1.0	200-40
Inverter + 60 Hz	10, 115 vac $\pm 5\%$, 1500 VA, sine wave	60	1.5	300-30	2	120	3.0	300-60	2	120	3.0	300-60
Line Regulator	23-50 vdc in, 28 vdc $\pm 5\%$ out, 1500 W	14	0.4	30-15	2	28	0.8	30-30	4	56	1.6	30-60
Feeder Control Relays	Protect and control power source, feeders, buses	1.2	3.3×10^{-2}	50-2	26	31	0.9	50-54	32	38	1.1	50-64
Load Control Relays	Connect/disconnect load, protect dist. wires	0.2	1.0×10^{-2}	100-2	58	12	0.6	100-116	70	14	0.7	100-140
Feeder Cables	Deliver power from source to load buses	150 ^a		0-20 ^a	150 ft	25	-	0-3	200 ft	30	-	0-4
Distribution Cables	Deliver power & signals to individual loads	20 ^a		0-20 ^a	26,500 ft	530	-	0-6	38,000 ft	700	-	0-7
Totals						1868	41.8	680-809		2363	44.1	920-930

^a Per 1000 ft

six hour power and energy profile for the Baseline Mission is shown in Figure 7-9. The 24-hour average power level is 5.4 KW with an average power during the active experimentation period of 7.0 KW. Energy requirement for the most active day is 129 KW-hr with a total mission energy requirement of 633 KW-hr. The highest peak load including power conditioning and distribution losses is 15.2 KW for two minutes (Table 7-10), including 1.3 KW of power conditioning and distribution loss.

Power Generation. Power generation is identical to that of the low cost system. The fuel cell is just adequate to supply the 7.0 KW average Sortie requirements. However, the peak load of 15.2 KW exceeds the specified 10 KW fuel cell capability. A peaking kit is required to supply the excess peak.

An auxiliary kit consisting of a 70 amp-hr silver-zinc battery provides peaking power to supplement the two radar experiment packages (5.5 KW bus load). The battery is recharged from the fuel cell. Recharge losses in the peaking kit are 2.4 KW-hr per day or 11.8 KW-hr for the five day experimentation period. The total mission energy requirement is thereby increased to 645 KW-hr.

The liquid oxygen and two liquid hydrogen tanks selected for the low cost mission are adequate to store the larger quantity of reactant required.

Distribution, Conditioning, and Control. Distribution, conditioning and control is essentially identical to that of the low-cost Sortie, except that there is an additional peak load experiment bus and additional load remote circuit breakers and voltage regulators for the added experiments (see Table 7-9).

7-27

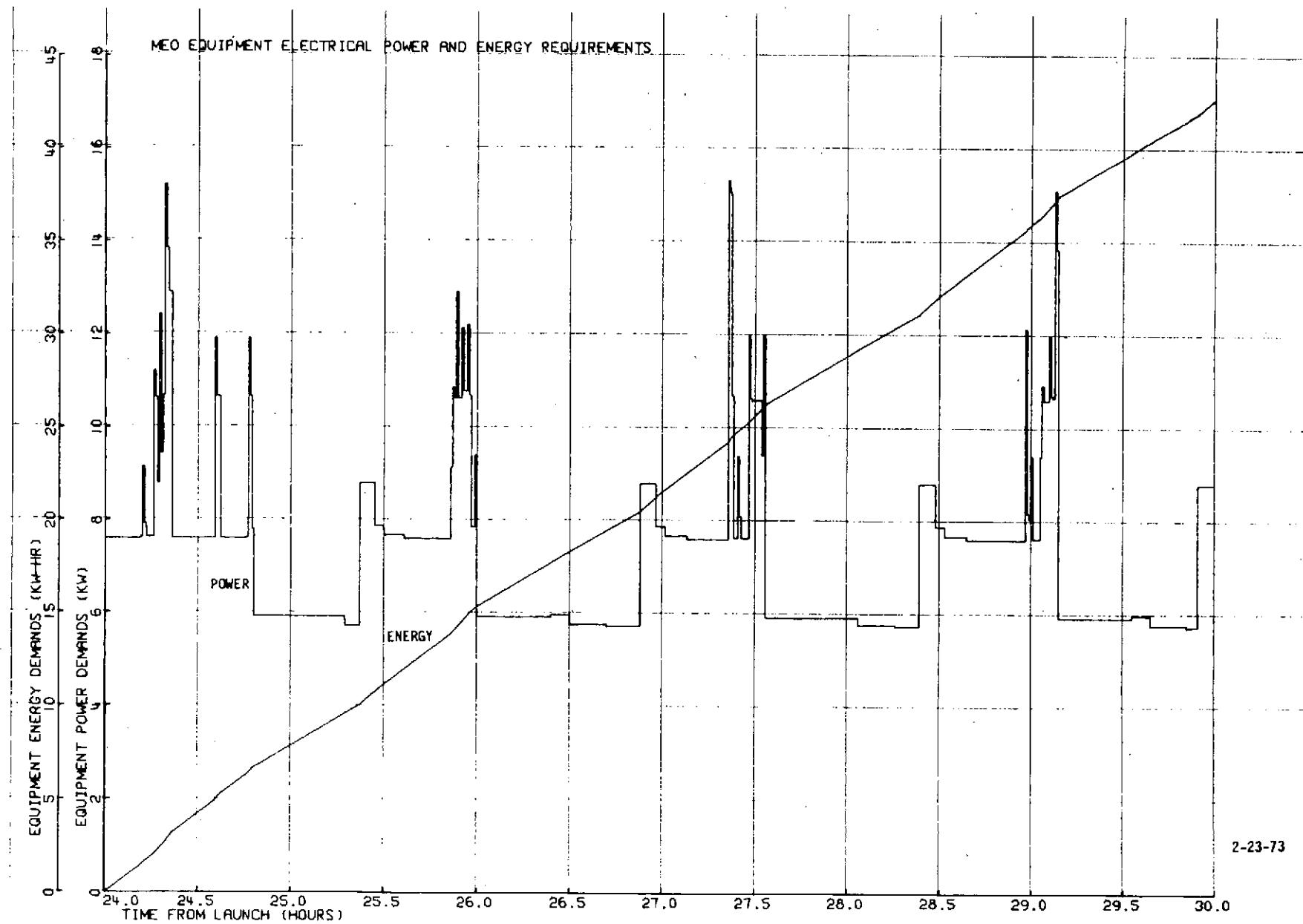


Figure 7-9. MEO Equipment Electrical Power and Energy Requirements

Table 7-10. Peak Power Requirements (Watts)
Baseline System

Subsystem	28 Vdc <u>+15%</u>	28 Vdc <u>+5%</u>	115/200 Vac, 400 Hz, 3Ø	115 Vac, 60 Hz, 1Ø
Experiment Sensors		10,000		
Thermal Control	75		225	
Environmental Control			240	
Data Management				
Computer BIU	6			
BIU's	28			
Computer				20
Command Decoder	2			
Frequency Synthesis Timer	8			
Buffer and Data Formatter	31			
Voice Annotation Recorder				10
Tape Recorder		180		
Transmitter	50			
Multiplexer	6			
Display and Control				
Console				2,100
Microfilm Reader				600
Test Equipment				30
Attitude Determination				
Star Tracker	8			
Gyro Reference	12			
Sensor Electronics	19			
Lighting			200	
Crew Chairs	80			
Total Peak Power Requirements	325	10,180	665	2,760

7.3 THERMAL CONTROL SUBSYSTEM

7.3.1 Introduction

The thermal control subsystem is required to maintain all experimental and support equipment on the Manned Earth Observatory within the allowable temperature range during all mission phases. It is also required to control the gradients within the mounting and support structure to acceptable levels. The MEO can be considered in two parts, the Sortie Laboratory and the pallet, for the purposes of describing the thermal control subsystem. In the Sortie Laboratory the primary thermal problem is to reject heat to space at an acceptable maximum temperature. On the pallet, the thermal problem is two-fold. When the components are operating it is necessary to reject the heat dissipation to space at an acceptable maximum temperature, and when they are non-operating the components must be maintained above their lower temperature limit for survival.

The most efficient means of heat removal is to mount the equipment on a cold plate through which a cold fluid is circulated. This approach is more efficient than forced air convection due to the high heat transfer coefficients in the liquid systems and the capability of cooling the equipment at higher temperatures. Normally forced-air systems are limited to about 75° F due to crew comfort considerations and they require high power for circulating the air. A forced air system would be difficult to interface with the pallet and to use for pallet component thermal control. Electronic equipment with cold plates normally can operate with 105° F coolant outlet temperatures; the higher the outlet temperatures the simpler the heat rejection function and the more efficient the system. This type of system is readily interfaced with the pallet by simply passing fluid lines through the pallet structure to the components mounted on cold plates. Thermal control in the Sortie Laboratory will rely heavily on cold plate mounts for the equipment wherever practical. In cases where this approach is not practical, forced-air convection will be used. The thermal control subsystem on the pallet will use a combination of cold plate mountings, multi-layer thermal insulation, and heaters with radiators using properly selected thermal-control coatings. Where component support structure on the pallet has critical alignment requirements, thermostatically controlled heaters

will be provided on the structure and the structure/heater combination will be covered with multilayer insulation to minimize the heat loss. Where possible on the pallet, thermal-control coatings will be used to optimize the component temperatures.

Design Concept

The MEO coolant system design is shown in Figure 7-10. The system is fully self-contained within the MEO and no Shuttle interfaces are required. A three-loop design is provided. A water loop circulates cold fluids to the equipment inside the pressurized module. From the pressurized module, a Freon loop circulates cold fluids to the equipment outside the pressurized volume, and a second Freon loop rejects the heat to space via a space radiator. Heat from the water loop is transferred to the Freon loop for heat rejection by means of a heat exchanger. Each loop contains a pump and accumulator package for circulation and to account for leakage and thermal expansion and contraction. The sizing of each loop will be function of the total heat dissipation to be accommodated.

The Freon loops contain an ascent/descent heat sink to provide cooling during the mission phases when the space radiator is inside the Shuttle. The on-orbit thermal capacitor stores cooling capacity during cold orbital intervals for subsequent use during warm orbital intervals. The unit contains a phase-change material which freezes during the cold portions of the orbit and melts when the radiator is exposed during the warm portions of the orbit.

In the Sortie laboratory, the water loop provides cooling to a condensing heat exchanger and to a cabin heat exchanger. The condensing heat exchanger absorbs heat loads in the cabin due to water vapor generated by the crew and from experiment latent loads. The cabin heat exchanger absorbs loads from the crew and experiments which cannot be cooled by cold plates. The bulk of the electrical load in the Sortie laboratory is removed by cold plates through which the cool water is circulated. Since the remainder of the electronic equipment is cooled by forced convection, provisions must be made to assure air circulation. The bulk of the forced air cooled equipment will be located within the consoles. Forced convection is obtained by drawing air through the console with the cabin heat exchanger fan as shown in Figure 7-11.

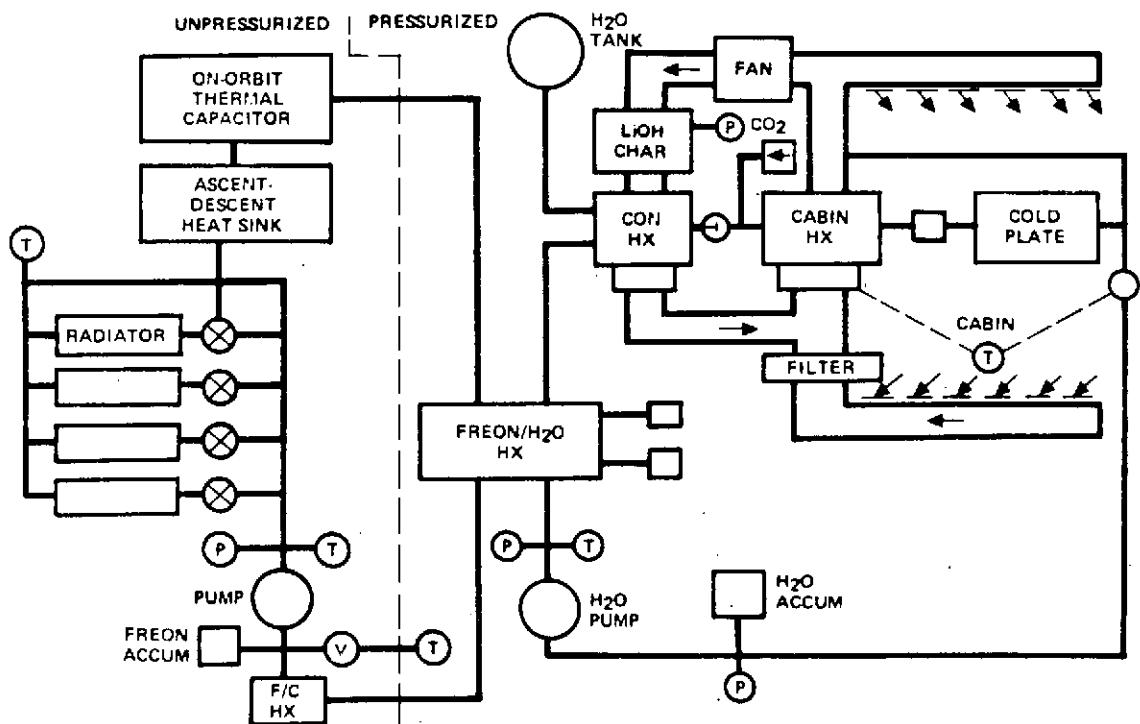


Figure 7-10. Coolant System Design

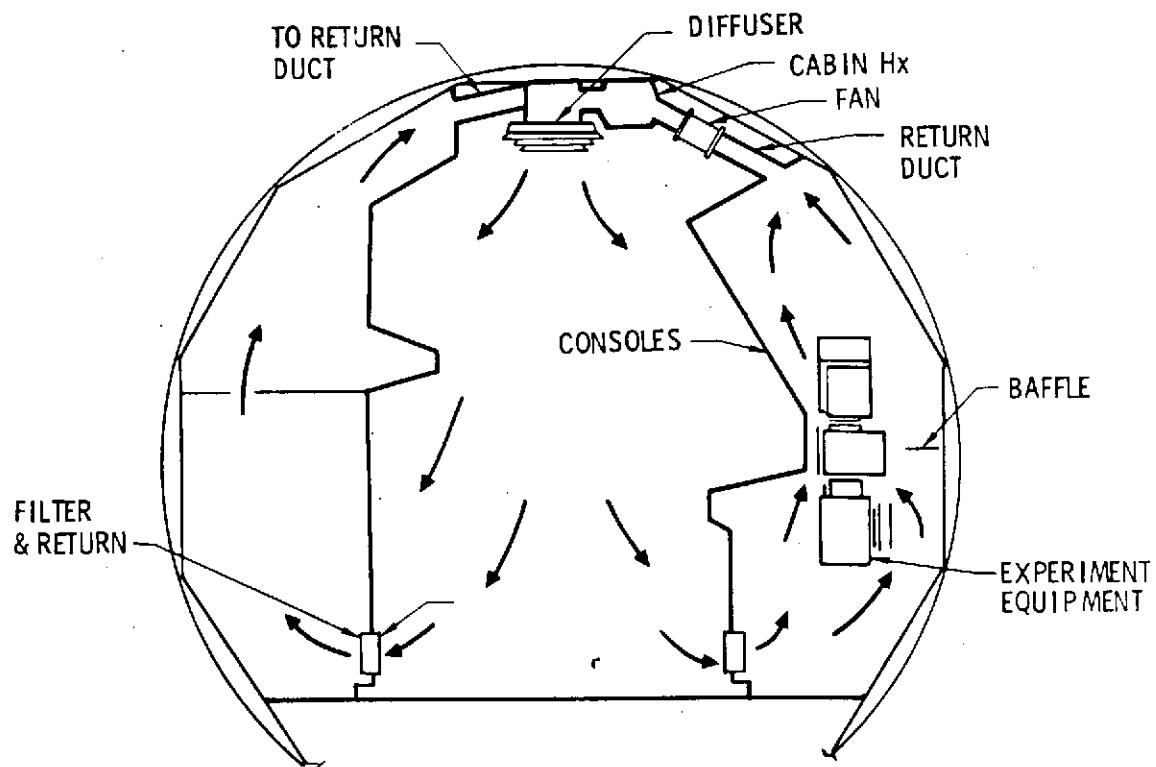


Figure 7-11. Environmental System

Temperature controlled air is distributed throughout the pressurized module by a diffuser system. The air passes through the column and then enters the consoles through filters and return grills. The air then passes across the console equipment and the flow paths are controlled by baffles to get the desired air flow distribution. Near the top of the consoles, the air is drawn through the return duct by a fan before passing through the cabin heat exchanger where the air is cooled prior to recirculation. Additional detail is shown on layout number PDO-268 (Sheet 2 of 2) enclosed with this report.

On the pallet, the Freon loop provides cooling to the electronics and instruments mounted on cold plates. The electronics associated with the sensors are mounted in equipment racks on the pallet. These equipment racks provide a cold plate mounting which is serviced by the Freon loop on the pallet. Where possible the instrument thermal control will be accomplished with passive techniques: thermal-control coatings, mounting interface control, multilayer insulation and radiator areas sized to accommodate the instrument heat dissipation. Thermostatically controlled heaters will be used on the support structure under multilayer insulation blankets and on instruments where it is not possible to maintain the lower allowable temperature during cold periods without augmenting the heat dissipation. Where necessary and practical, cold plate mountings will be provided for instruments. A detailed thermal analysis of the instruments mounted on the support structure will dictate the heater power requirements to maintain mechanical alignment. Deployable support structures will require a special insulation/heater design to assure that the deployment is not hindered.

8.0 MEO WEIGHT SUMMARY

Table 8-1 lists weight estimates for several configurations of the MEO preliminary design for the pollution mission. These include the baseline 29-sensor system and the low cost 16-sensor configuration. For each, weight estimates have been prepared based on utilization of the NASA/MSFC standard and short pressurized lab modules.

Note that the total weight estimates were arrived at by subtracting weights allocated to standard data management and crew station networks and displays from the NASA/MSFC Sortie Lab baseline weights, since these capabilities are provided in the autonomous, TRW-derived MEO system.

Table 8-1. MEO Weight Summary, Pollution Mission

ITEM	CONFIGURATION	WEIGHT (LB)			
		BASELINE MISSION		LOW COST MISSION	
		SHORT MODULE	STANDARD MODULE	SHORT MODULE	STANDARD MODULE
SORTIE CAN BASELINE WEIGHT		10,354	11,727	10,354	11,727
DATA MGT, NETWORKS, AND DISPLAY (STD)		(-1,423)	(-1,423)	(-1,423)	(-1,423)
30 FT PALLET STRUCTURE		1,600	1,600	1,600	1,600
SENSORS		8,800	8,800	4,347	4,437
GIMBALS		1,812	1,812	1,662	1,662
CONSOLES		600	600	600	600
DATA MANAGEMENT SYSTEM		96	96	96	96
TAPE RECORDERS		175	175	175	175
DATA AND ANNOTATION TAPES AND STORAGE		800	800	800	800
ELECTRONIC TEST EQUIPMENT		50	50	50	50
SPARE PARTS AND TOOLS		50	50	50	50
CREW CHAIR ASSEMBLY		86	86	86	86
ELECTRIC POWER (EXCLUDING TANKAGE)		919	919	669	669
TANKAGE		644	644	644	644
CABLING		800	800	555	555
TOTAL		25,333	26,736	20,355	21,728
		(11,480 KG)	(12,120 KG)	(9,230 KG)	(9,850 KG)

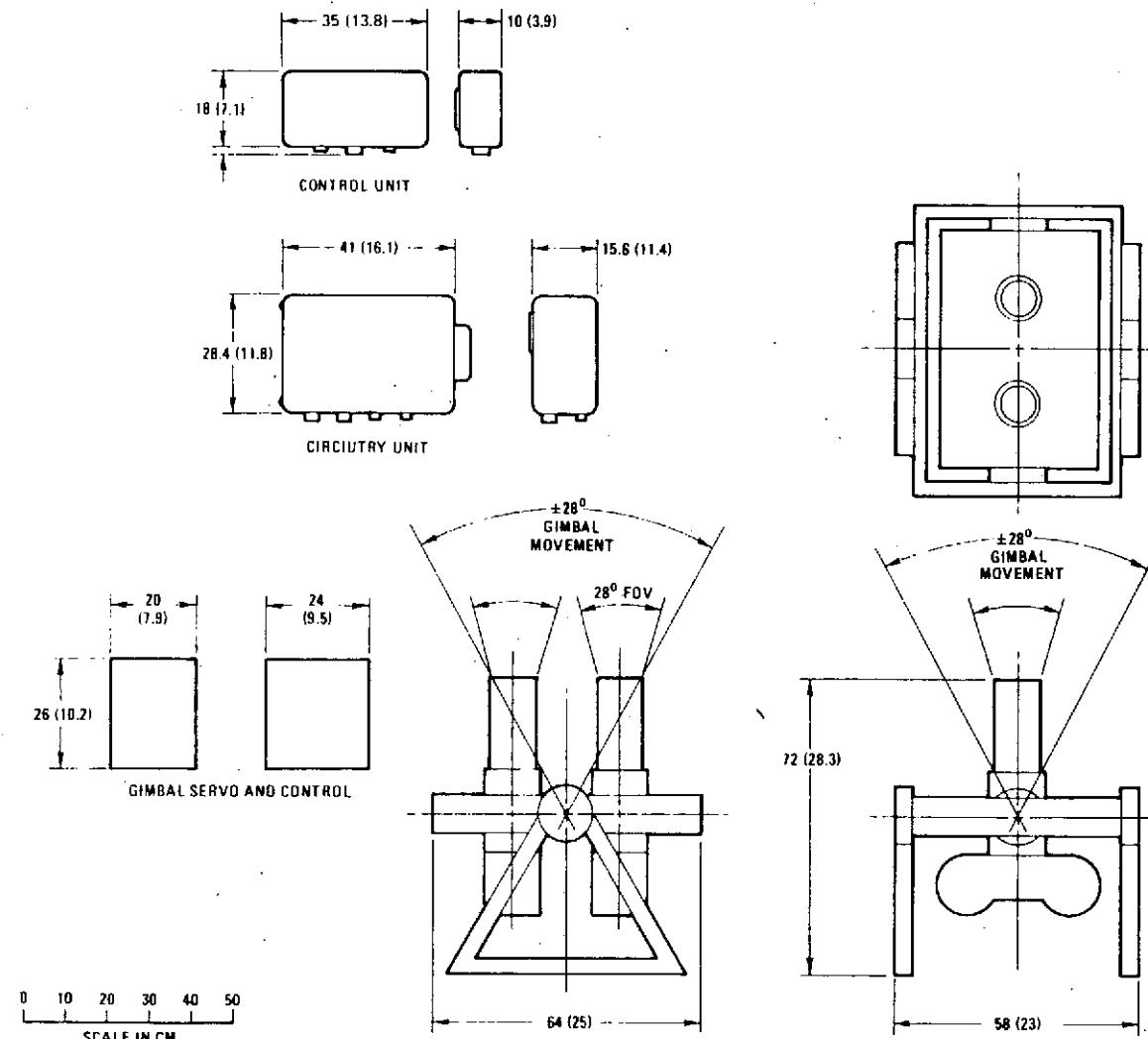
APPENDIX A

SENSOR CONFIGURATION DATA

In this Appendix data are presented defining the configuration of the sensors which have been selected as candidates for use in the payload of the Manned Earth Observatory. Performance specifications for each of the sensors were developed during Task 2 of the study and are presented as an Appendix to the Task 2 report. From the 33 candidate sensors, 29 have been selected for use in the Baseline Pollution Mission, and 16 were selected for use in the Low-Cost Pollution Mission.

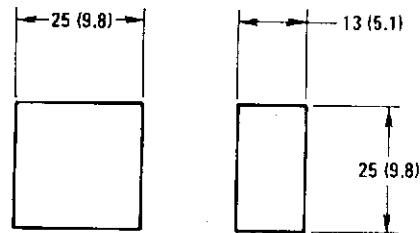
The source of the data is referenced for each of the configuration drawings where applicable. The configurations of sensors for which no data source is referenced have been developed by TRW Systems.

In Table A-1, the salient physical characteristics of the sensors are summarized.

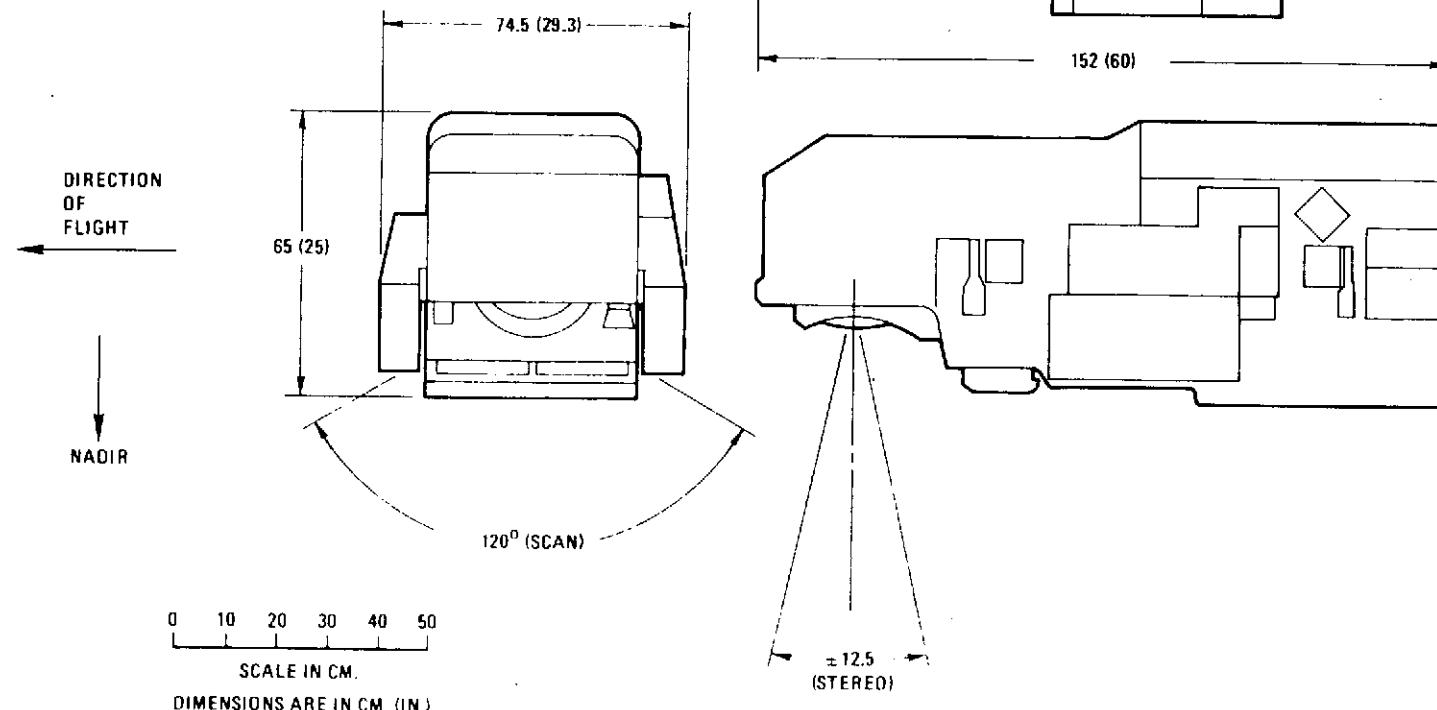


DIMENSIONS ARE IN CM. (IN.)

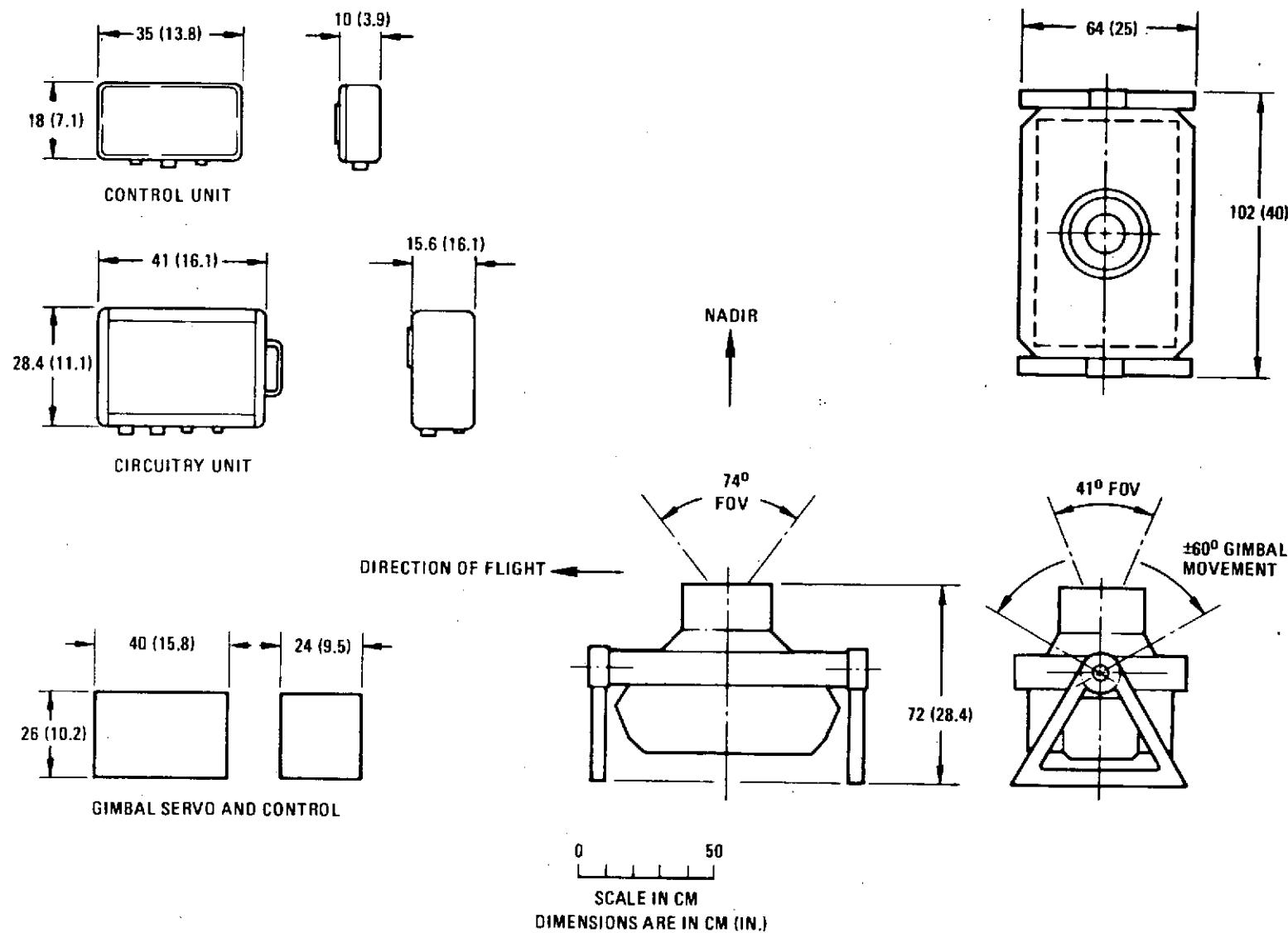
Sensor No. 2. Pointable Identification Camera System (70 mm Film)



CONTROL UNIT

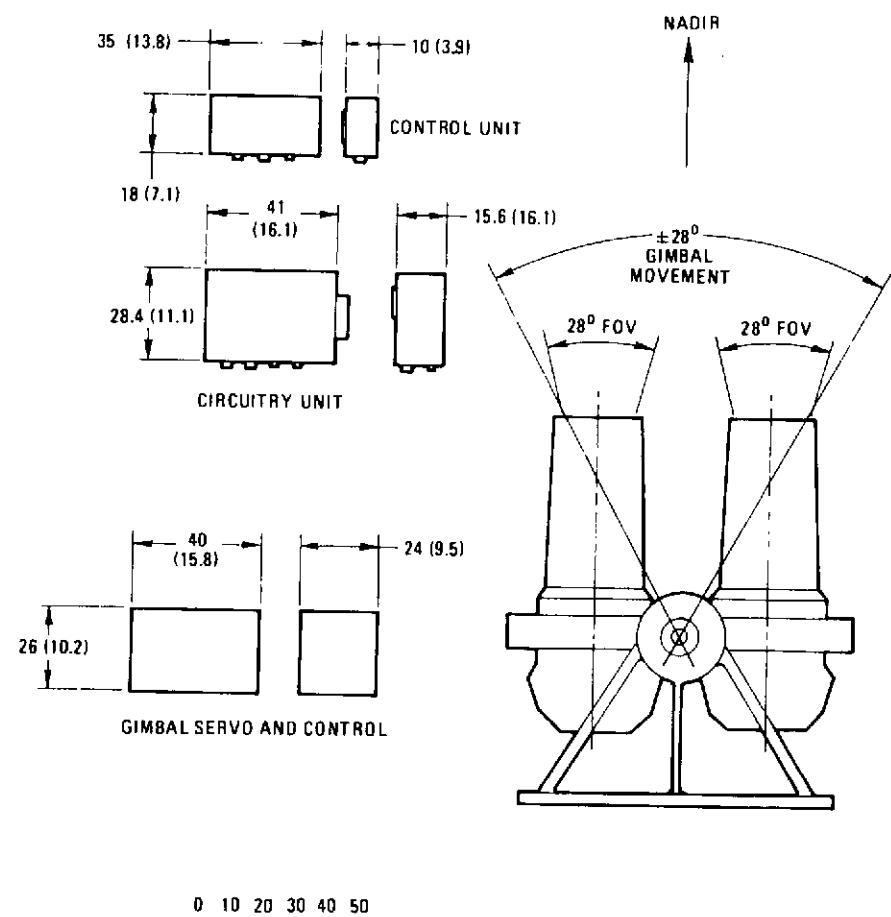


Sensor No. 3. Panoramic Camera

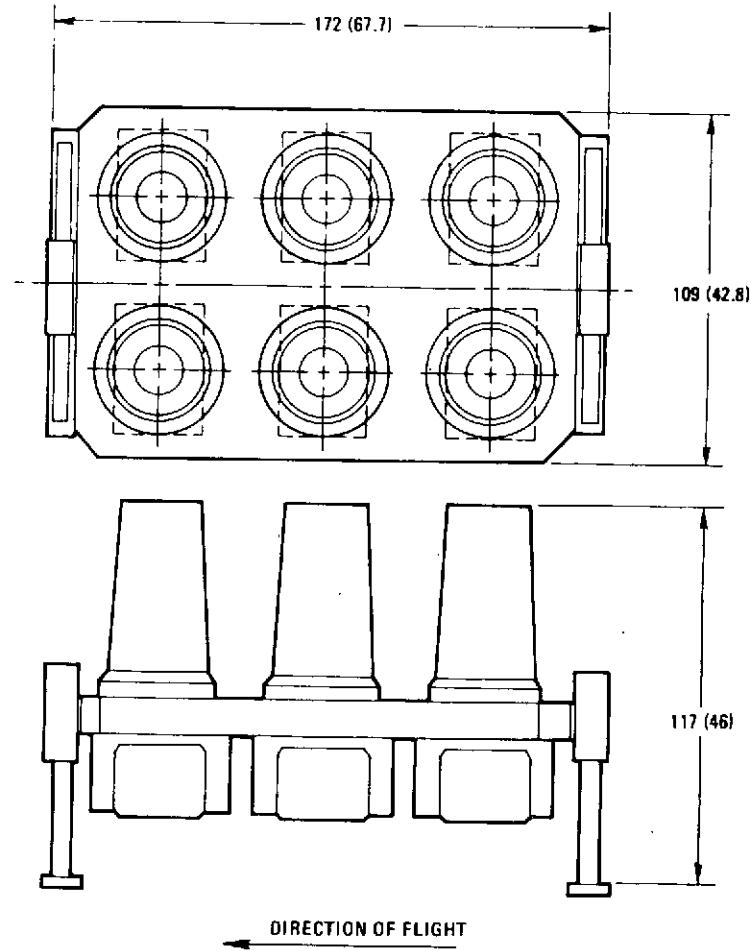


Sensor No. 4. Wide Angle Framing Camera (24 x 48 cm Film)

A-6

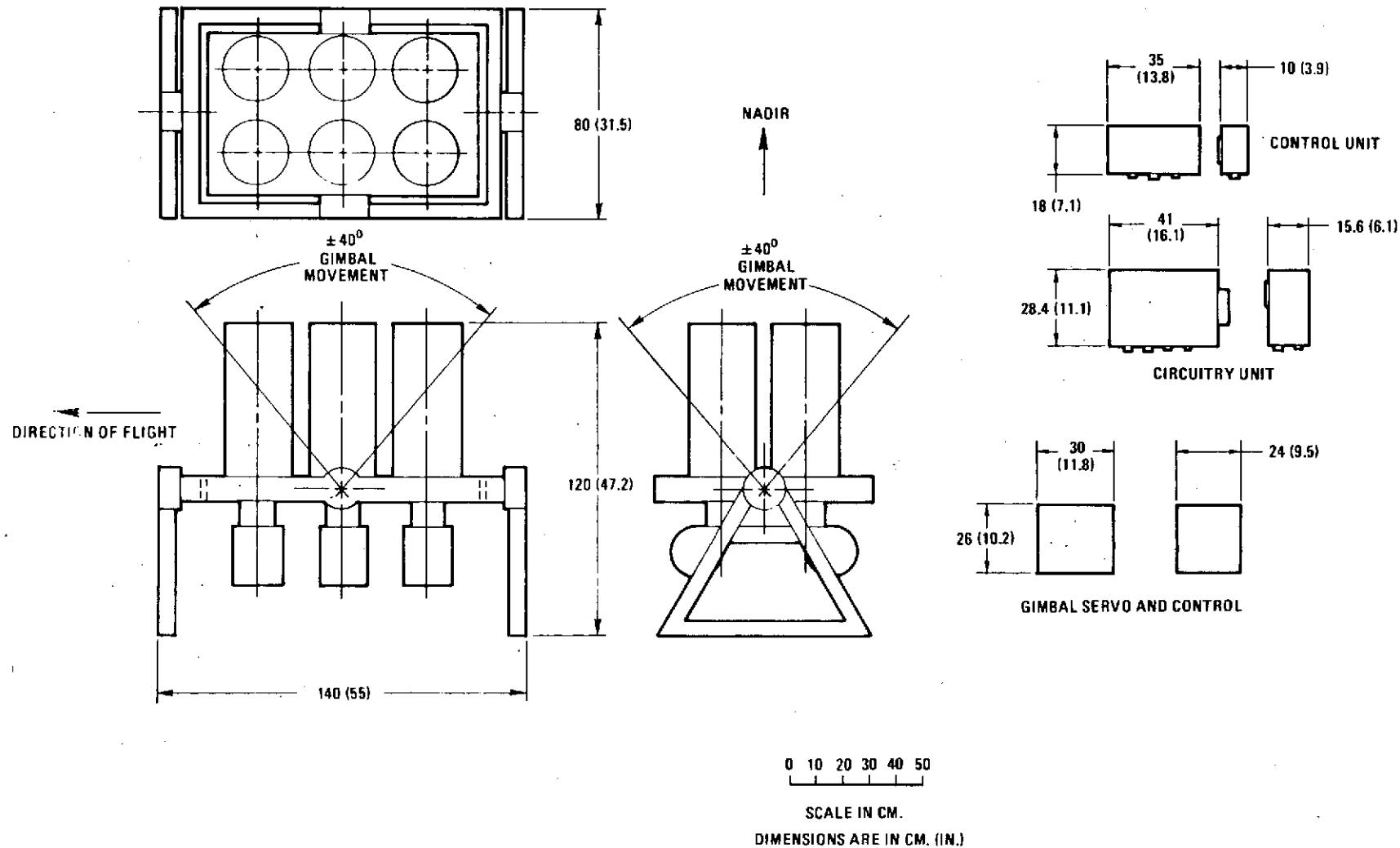


DIMENSIONS ARE IN CM. (IN.)

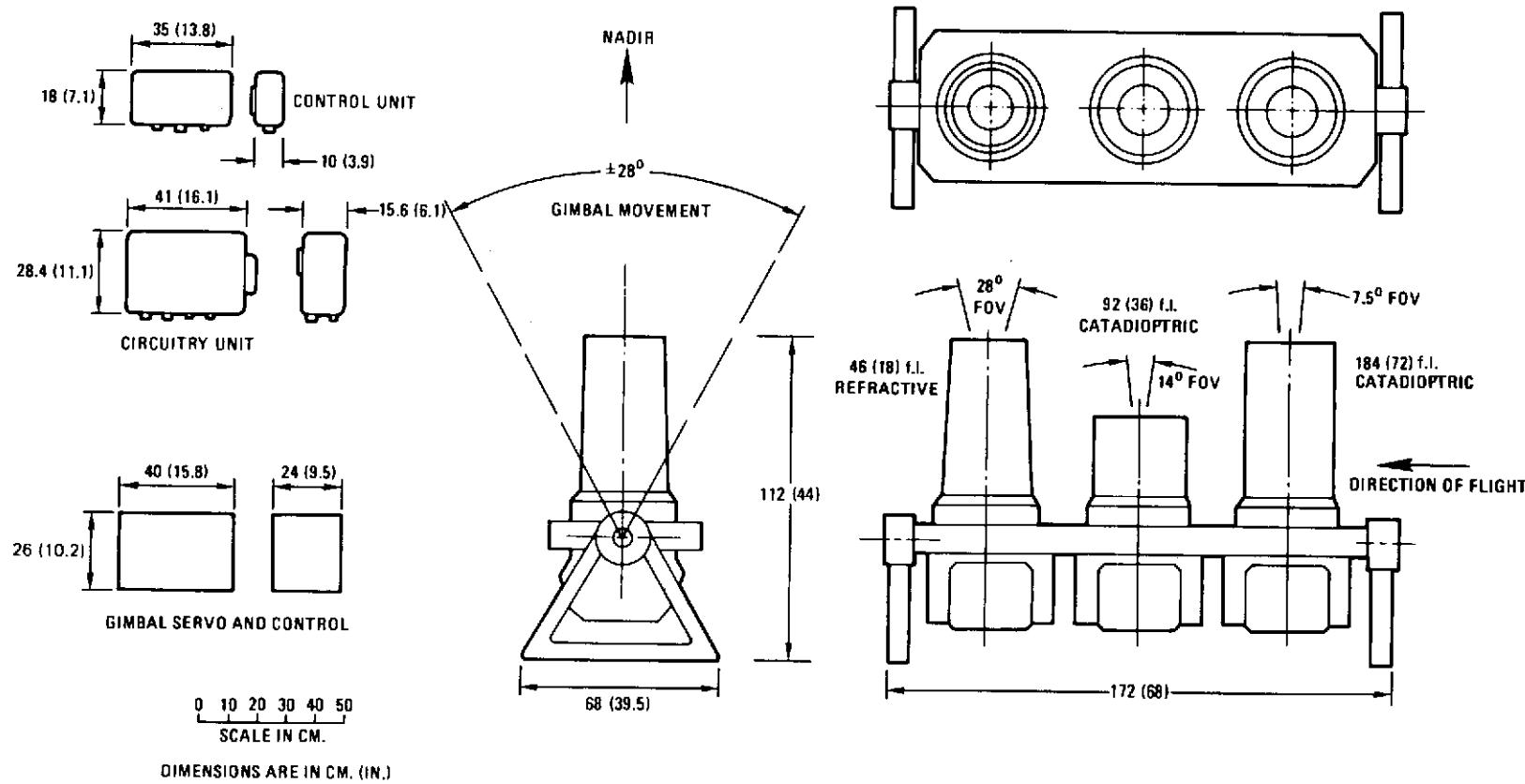


Sensor No. 5. Multispectral Camera System (24 x 24 cm Film)

A-7

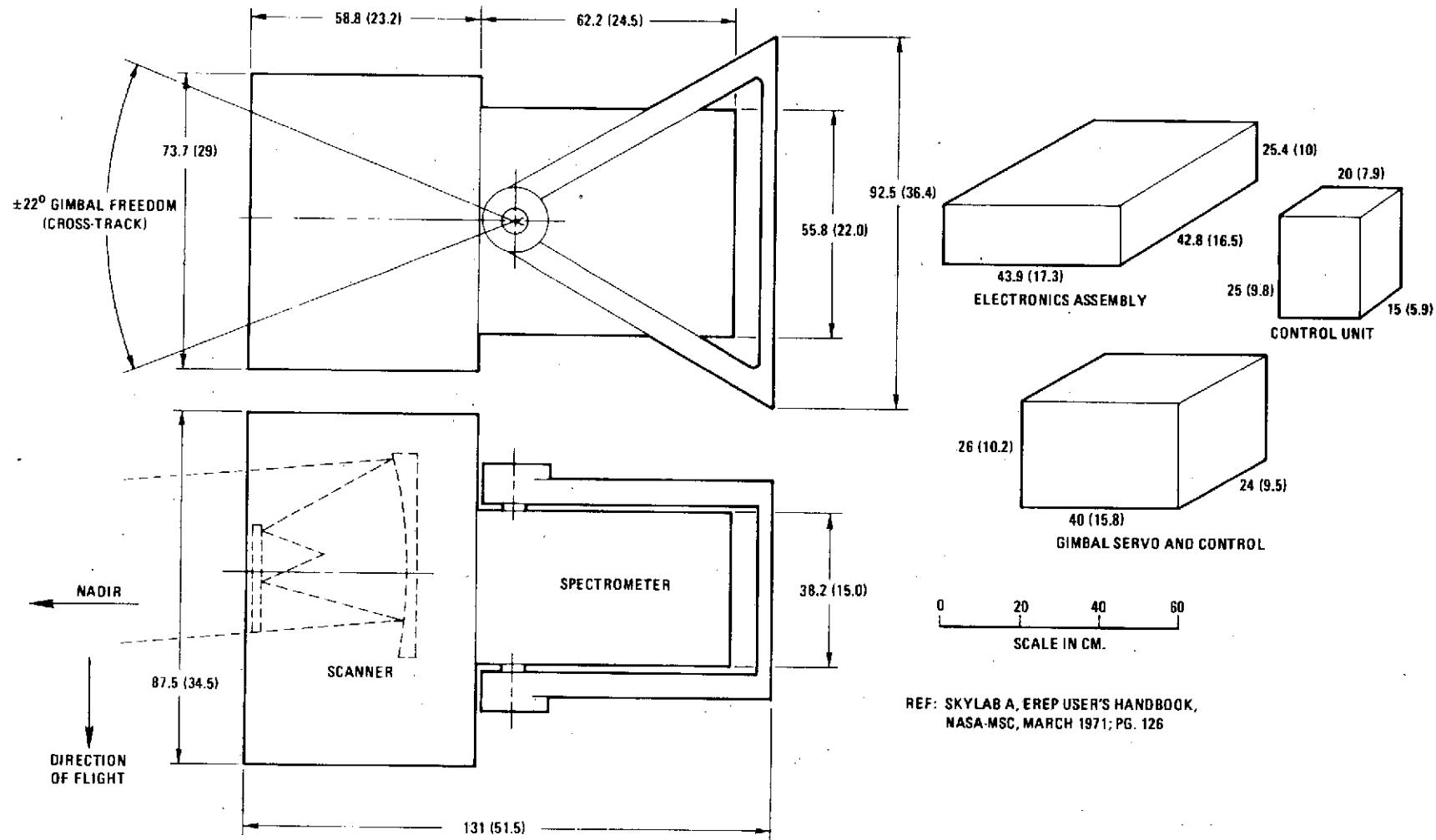


Sensor No. 6. High Resolution Multispectral Camera System (70 mm Film)

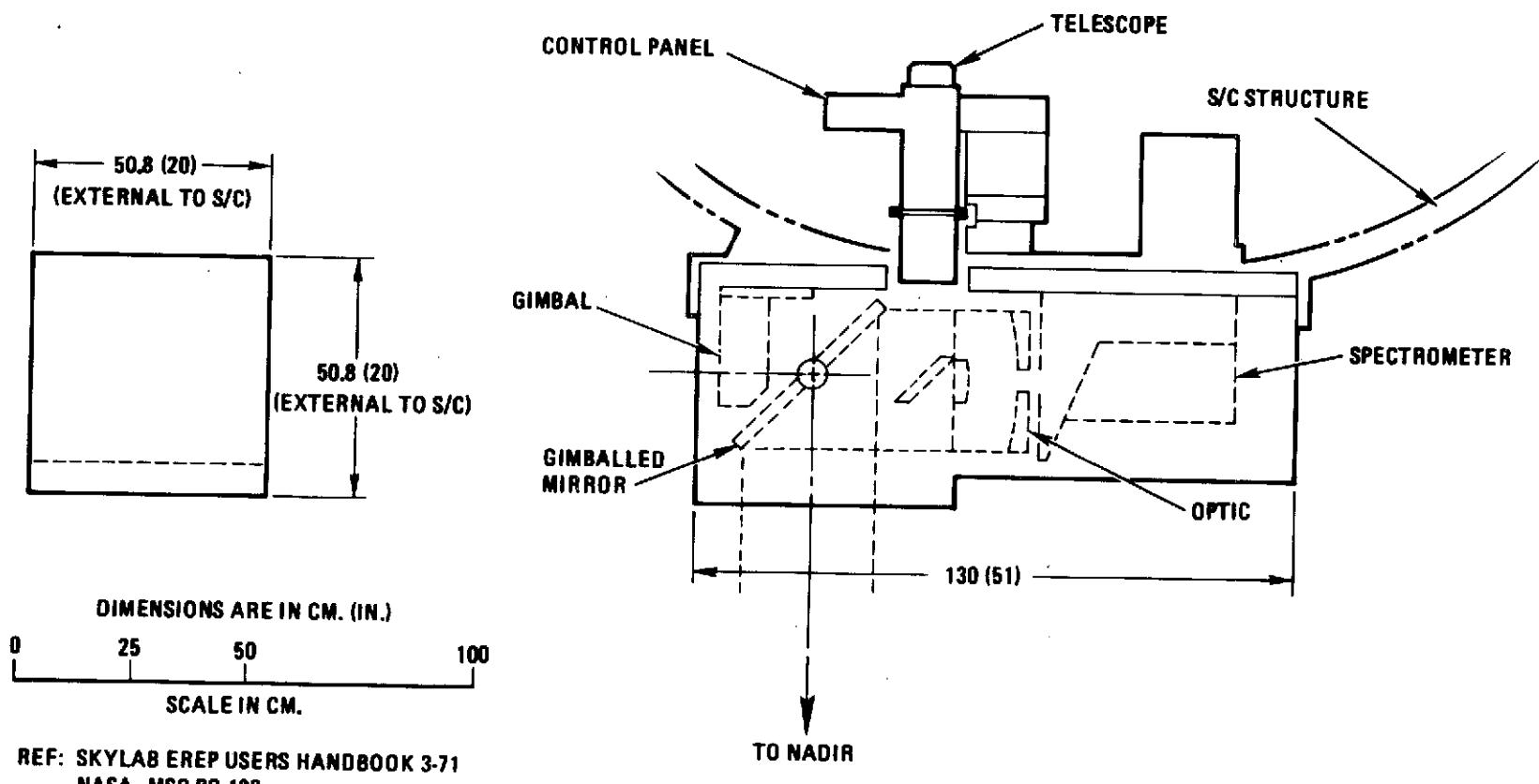


Sensor No. 7. Multiresolution Camera System (24 x 24 cm Film)

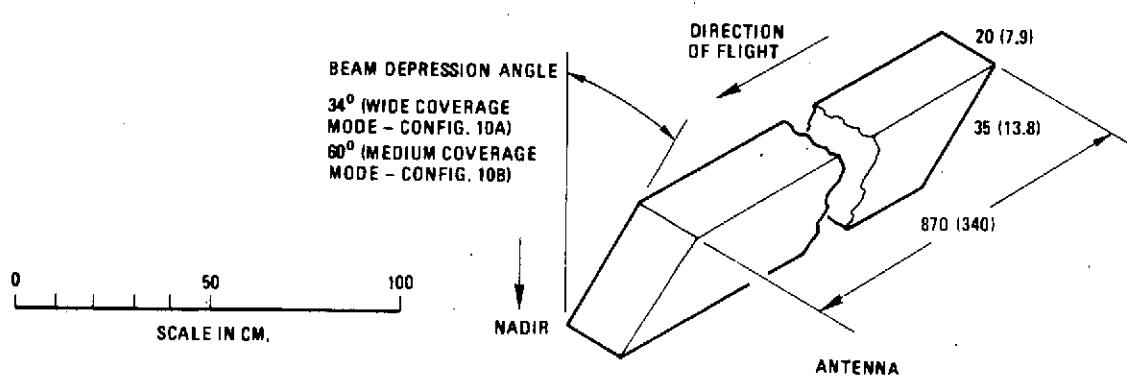
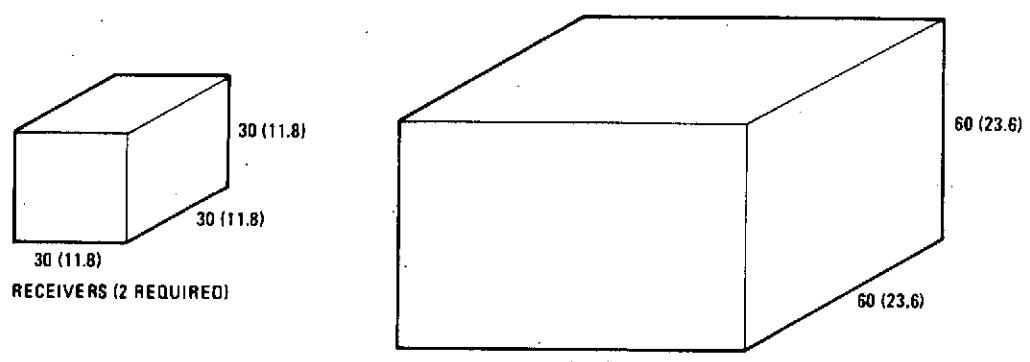
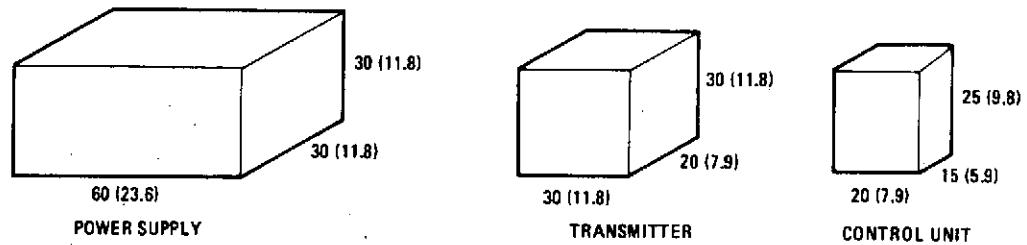
A-9



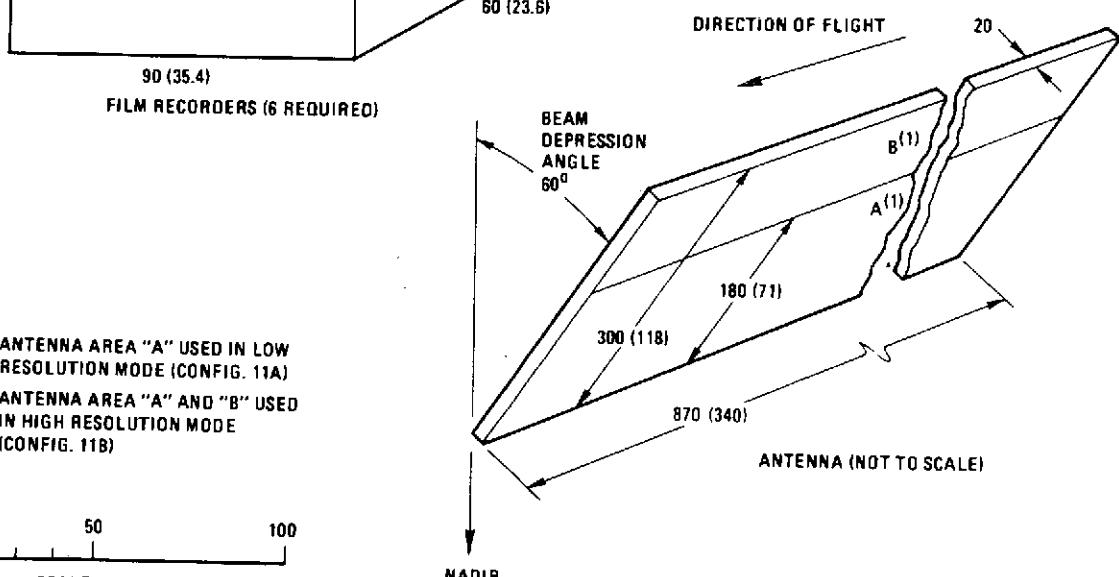
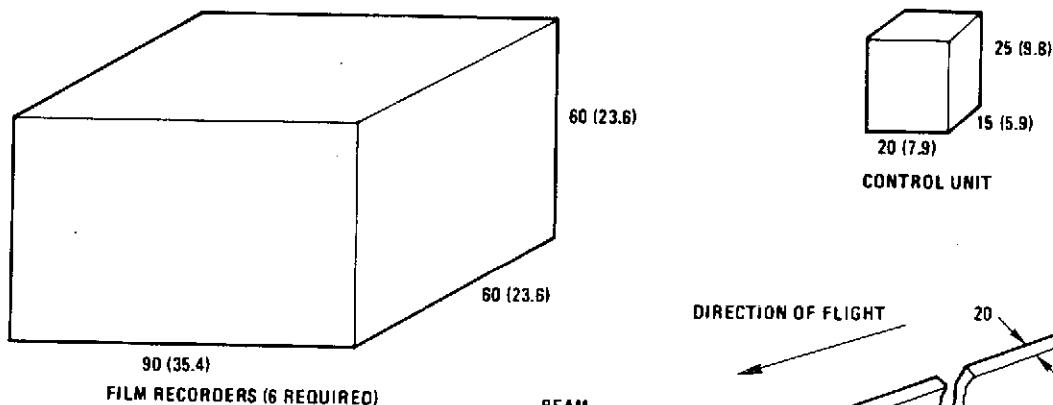
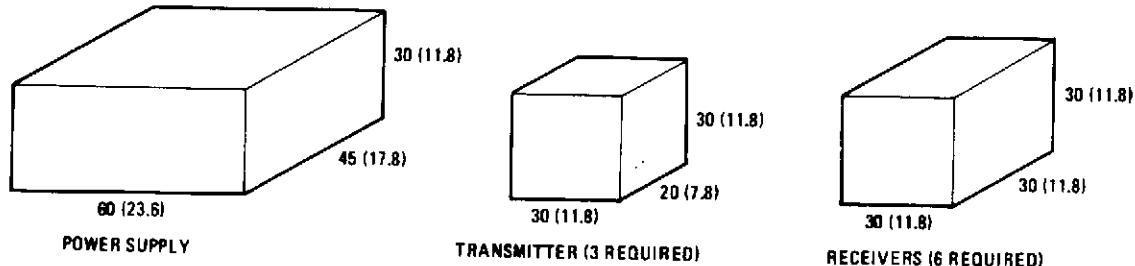
Sensor No. 8. High Resolution Multispectral Scanner



Sensor No. 9. LWIR Spectrometer

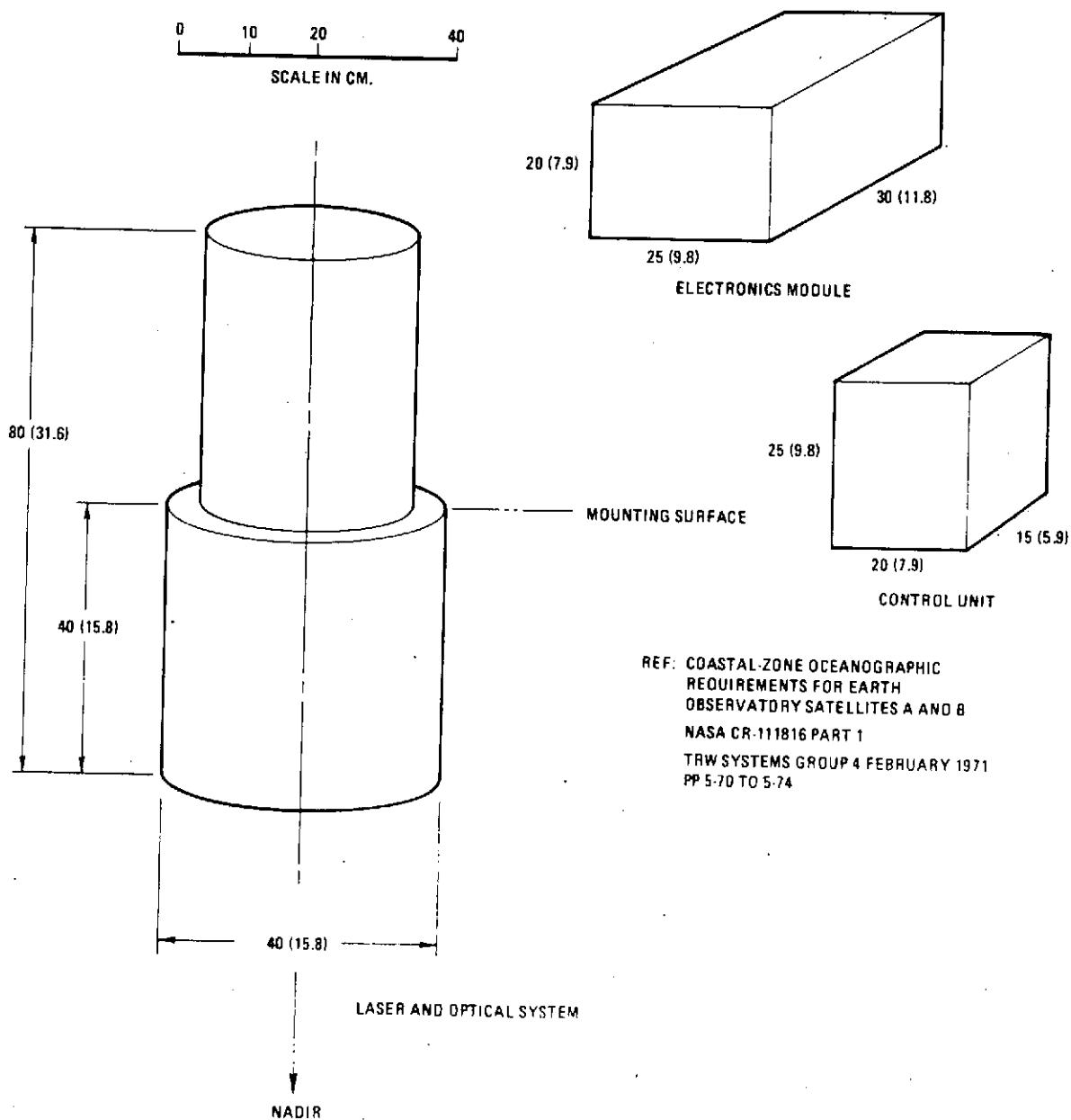


Sensors Nos. 10A/B. Wide Band Synthetic Aperture Radar

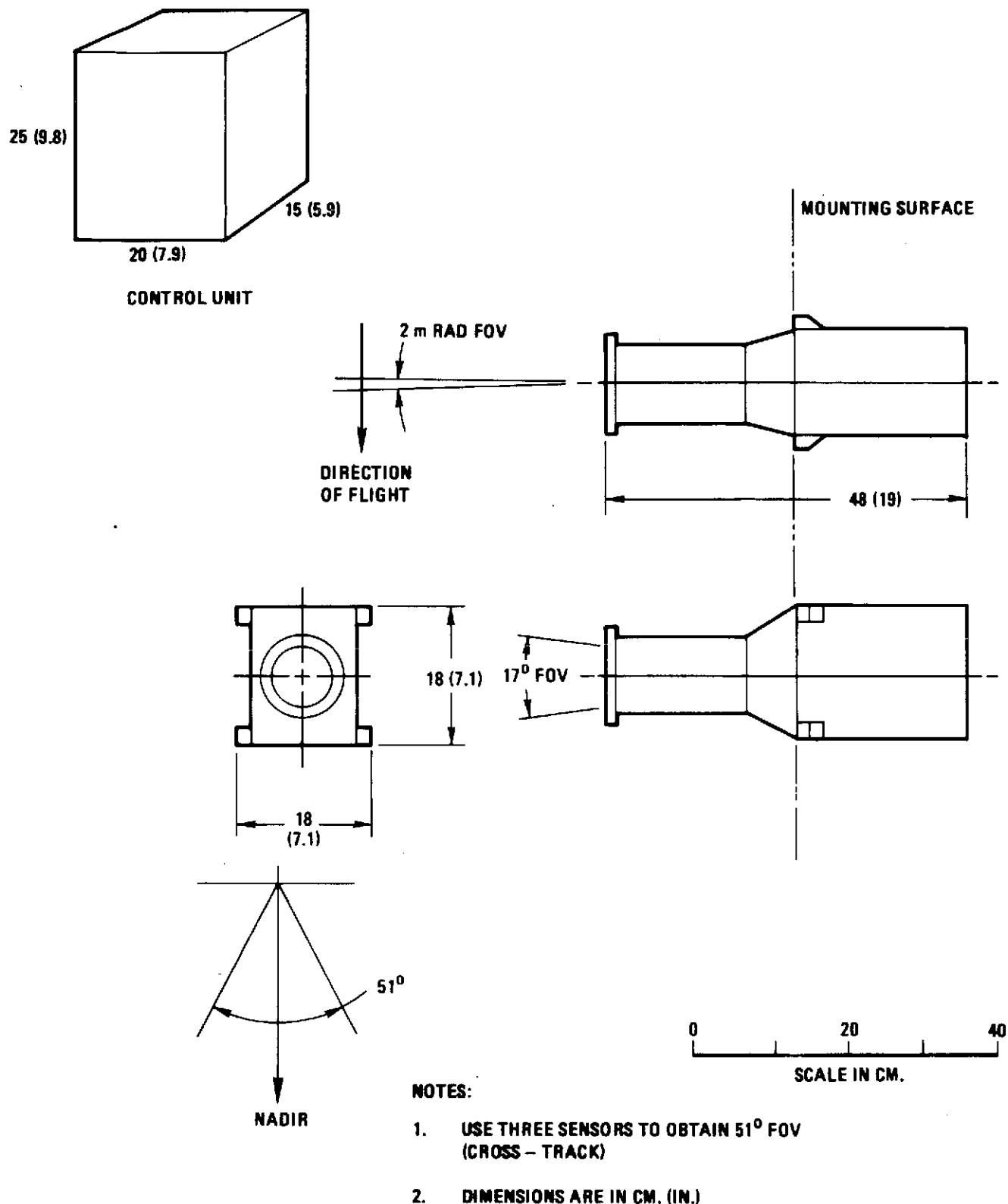


NOTES: ANTENNA AREA "A" USED IN LOW RESOLUTION MODE (CONFIG. 11A)
ANTENNA AREA "A" AND "B" USED IN HIGH RESOLUTION MODE (CONFIG. 11B)

Sensors Nos. 11A/B. Multifrequency Wideband Synthetic Aperture Radar

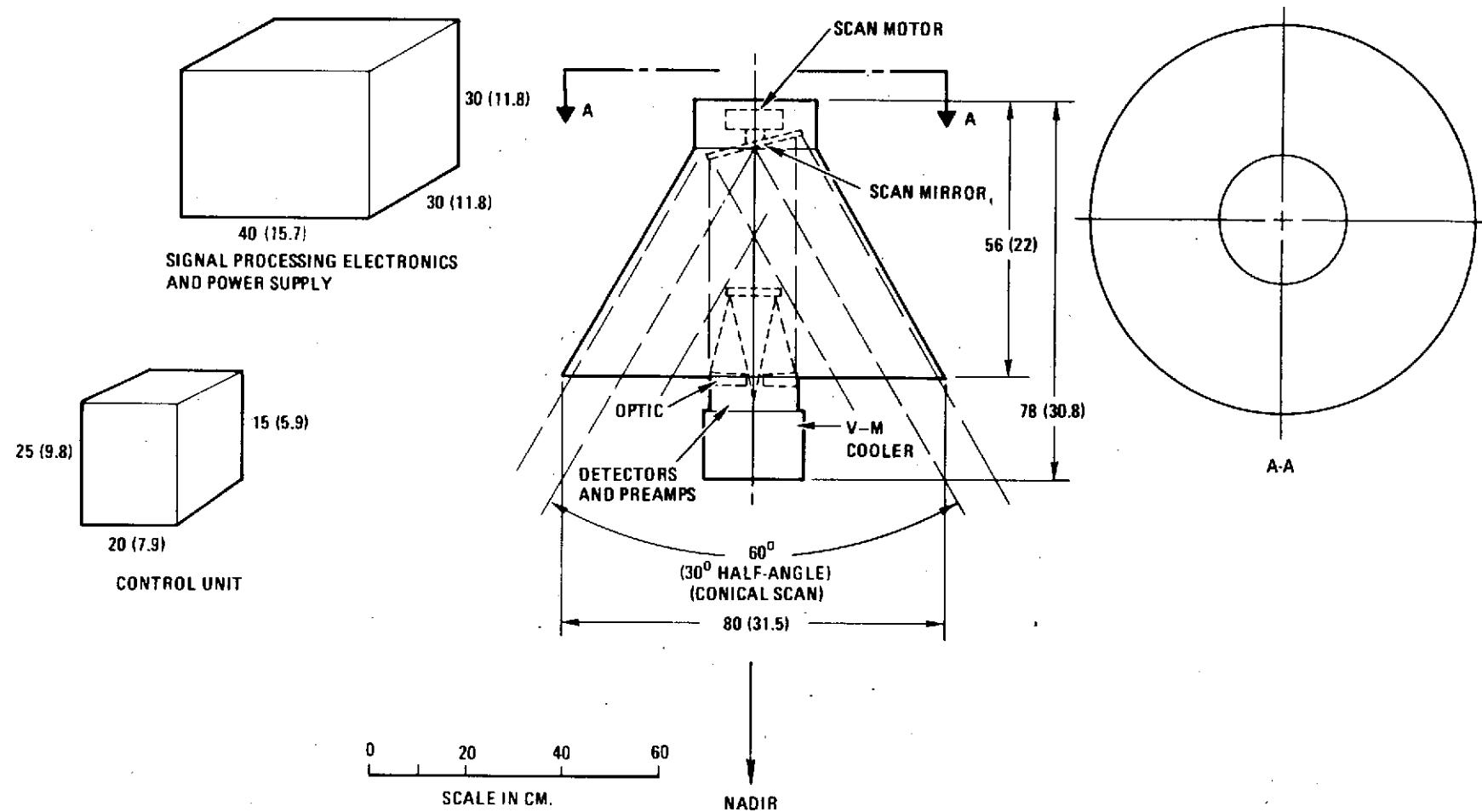


Sensor No. 12. Laser Altimeter/Scatterometer



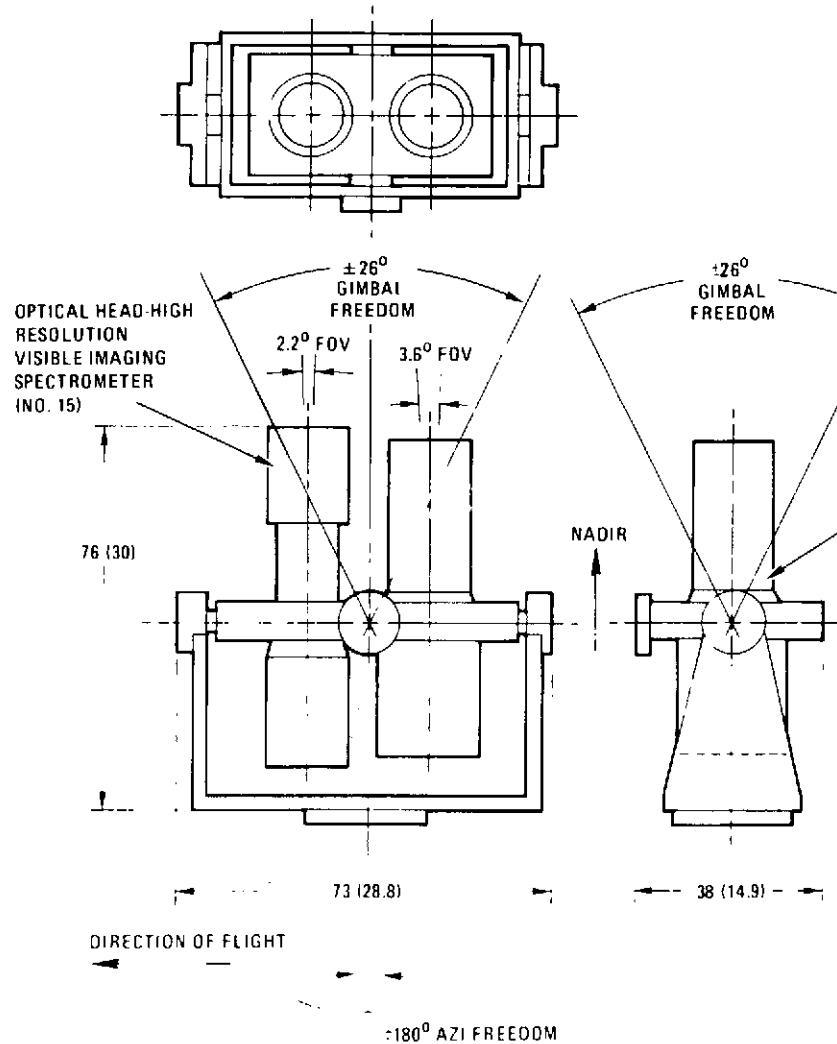
Sensor No. 13. Visible Imaging Spectrometer

A-15

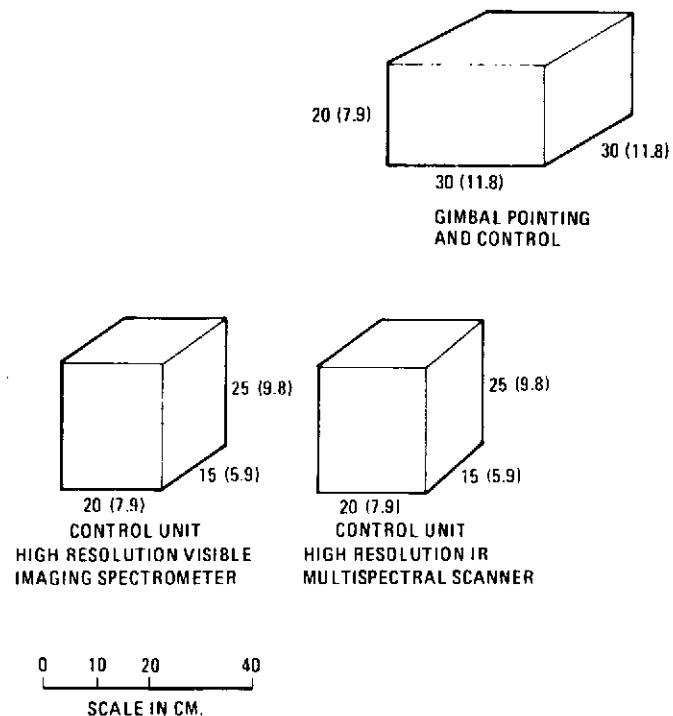


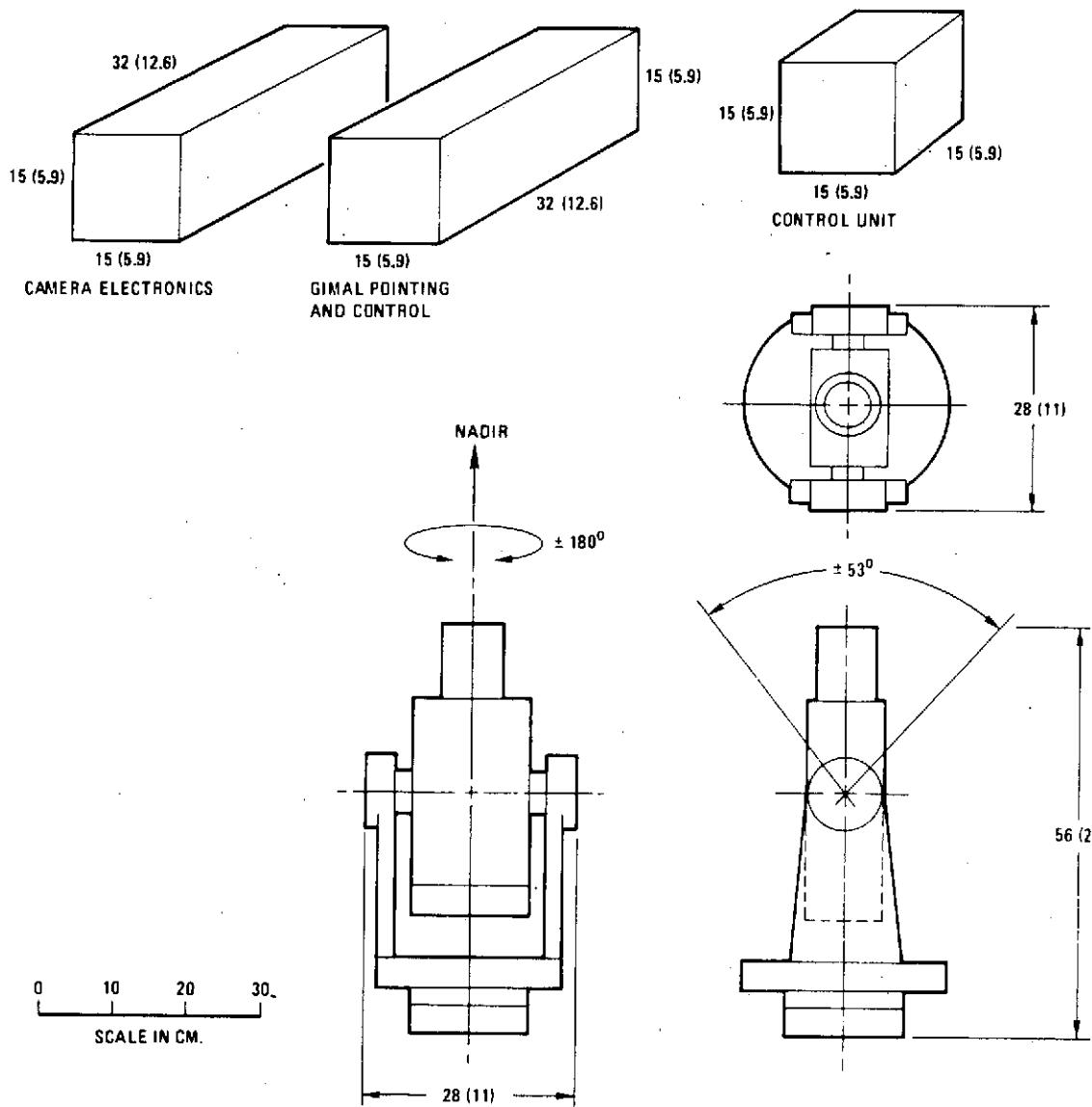
Sensor No. 14. IR Multispectral Mechanical Scanner

A-16

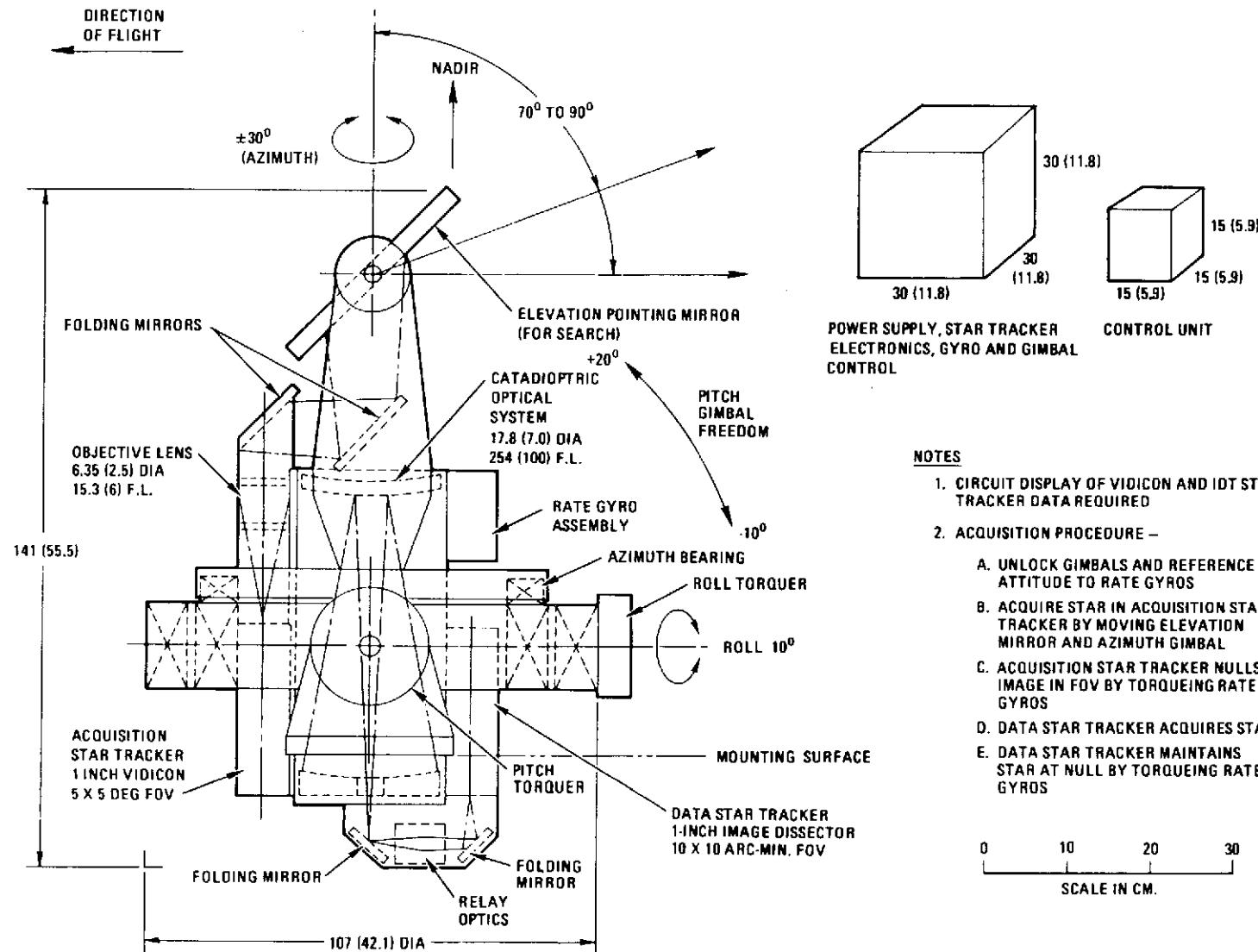


Sensors 15 and 16. High Resolution Visible Imaging Spectrometer and High Resolution IR Multispectral Scanner

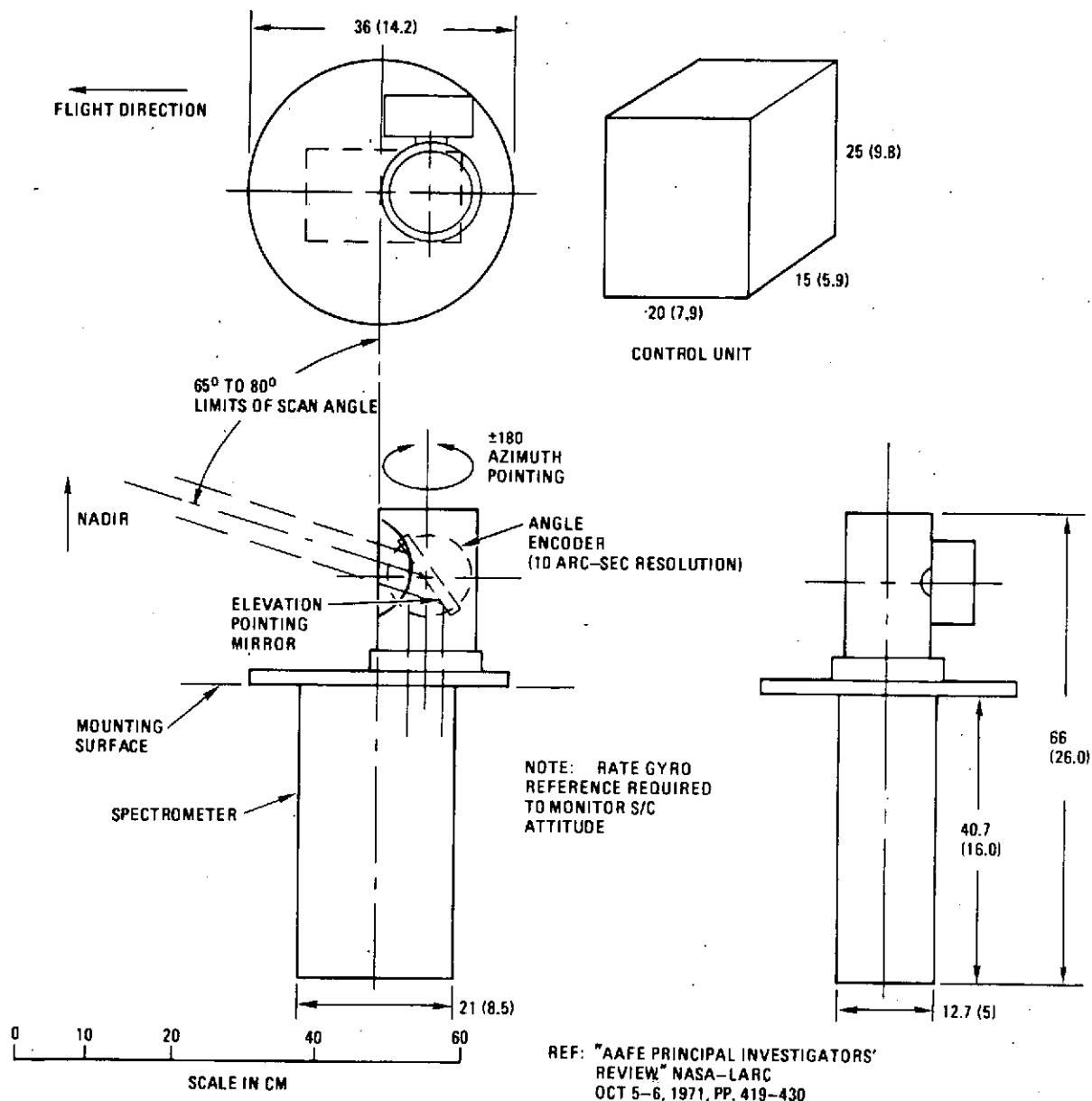




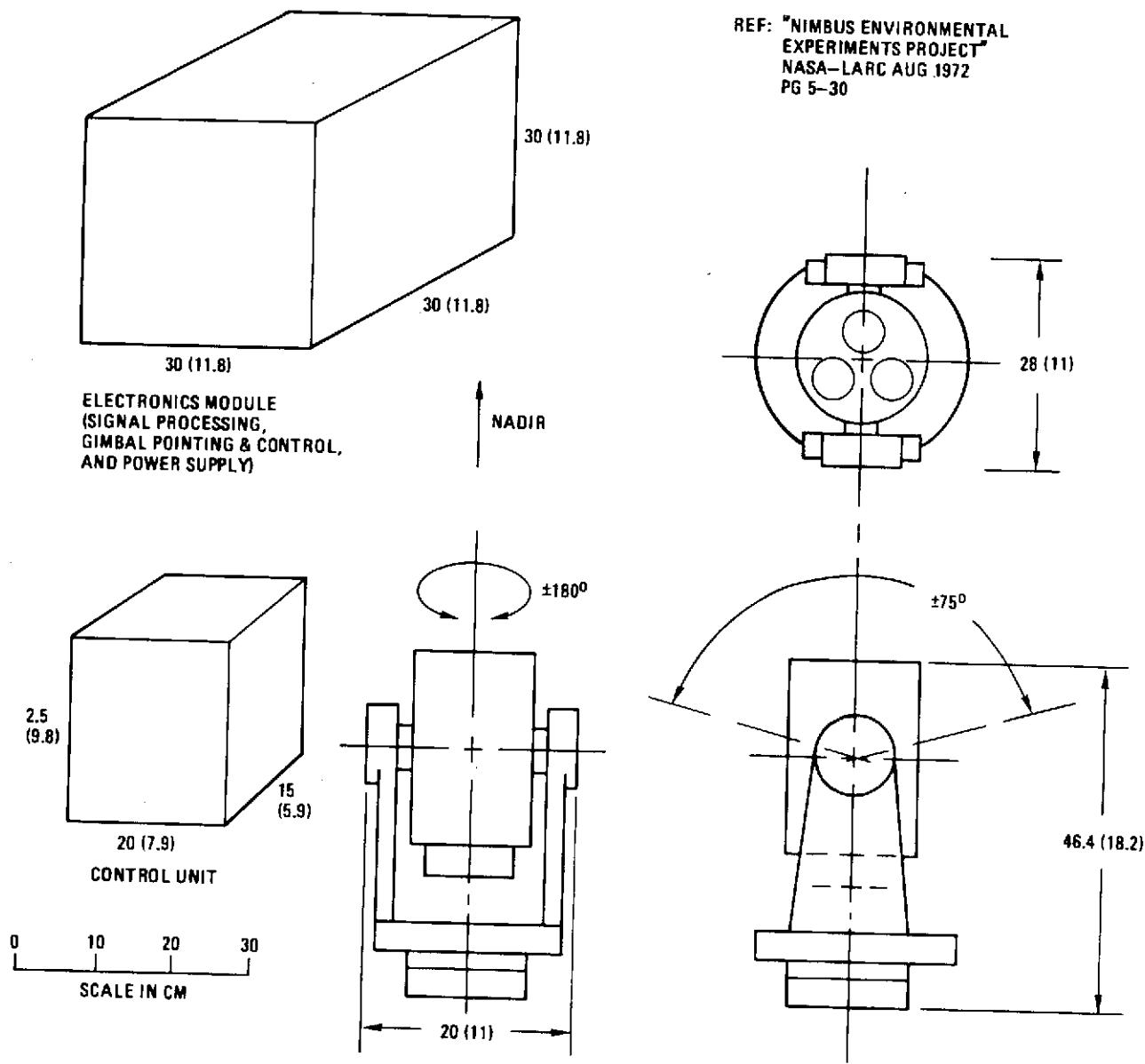
Sensor No. 17. Glitter Framing Camera



Sensor No. 18. Star Tracking Telescope

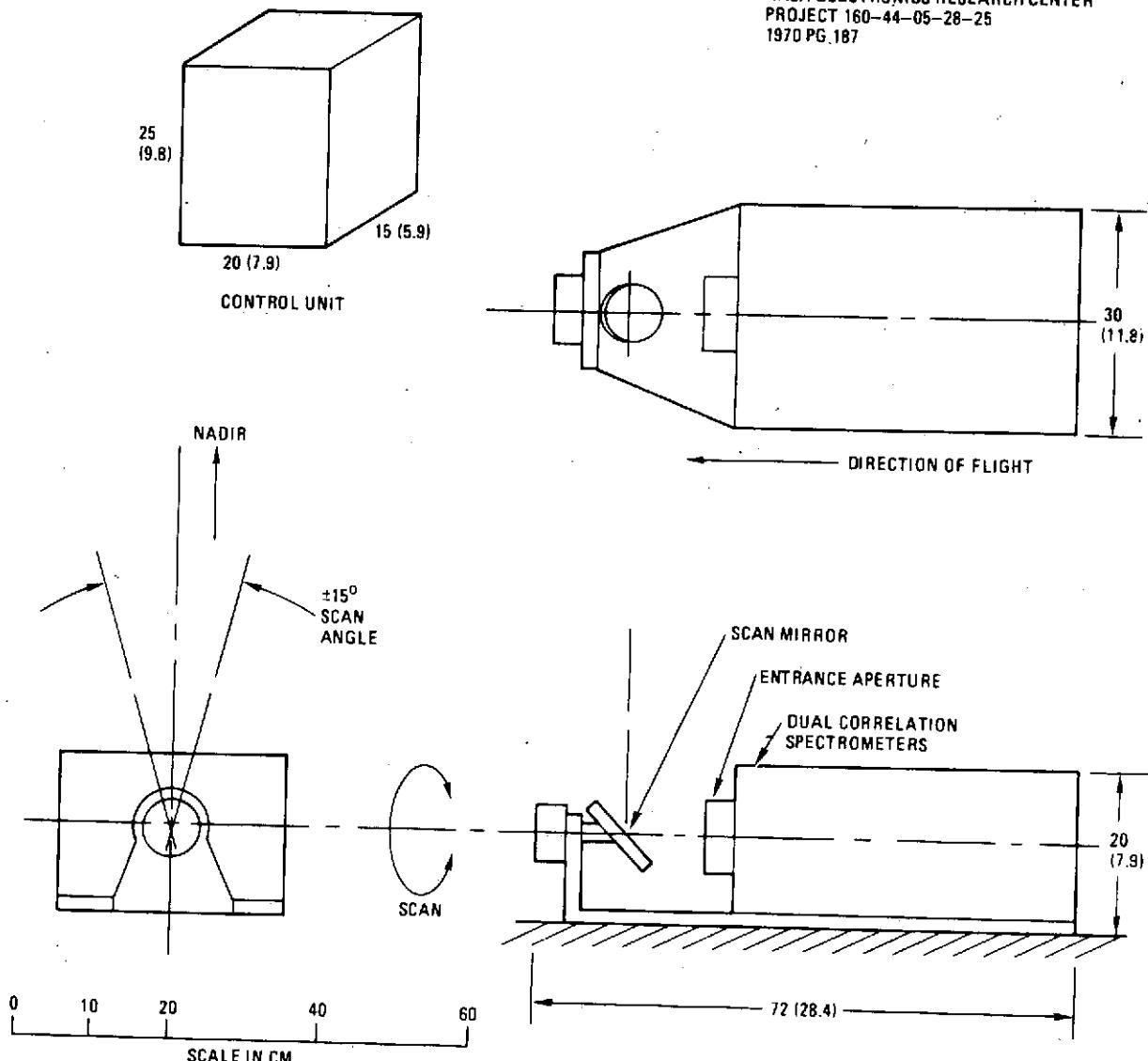


Sensor No. 19. Ultraviolet Upper Atmospheric Sounder



Sensor No. 20. Visible Radiation Polarimeter

REF: SPACE APPLICATION INSTRUMENT SURVEY
NASA ELECTRONICS RESEARCH CENTER
PROJECT 160-44-05-28-25
1970 PG. 187

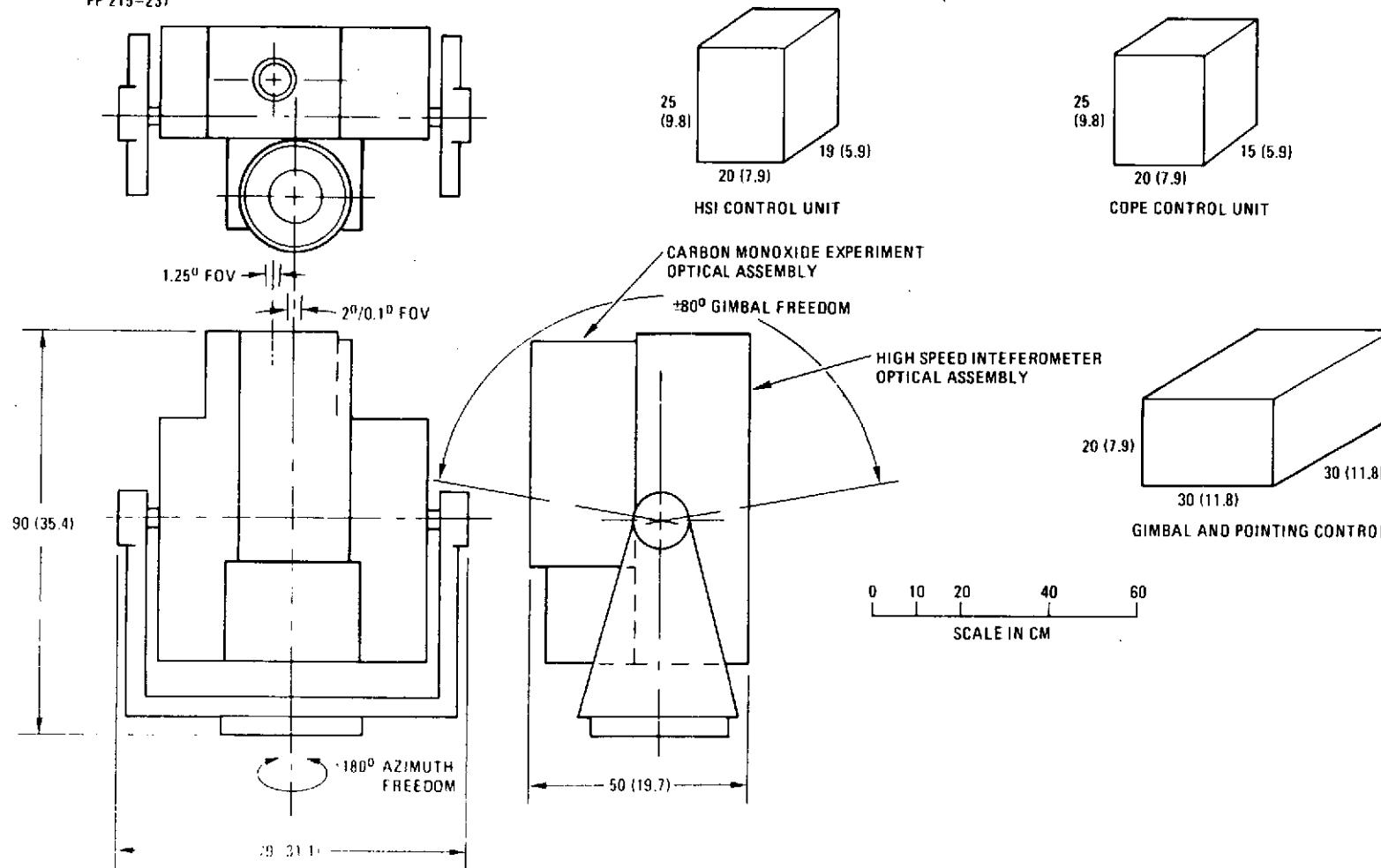


Sensor No. 21. Air Pollution Correlation Spectrometer

REF: 1) HIGH SPEED INTERFEROMETER BRIEFING CHARTS AND
INFORMAL EARTH OBSERVATION DATA SHEETS, OCT 1972

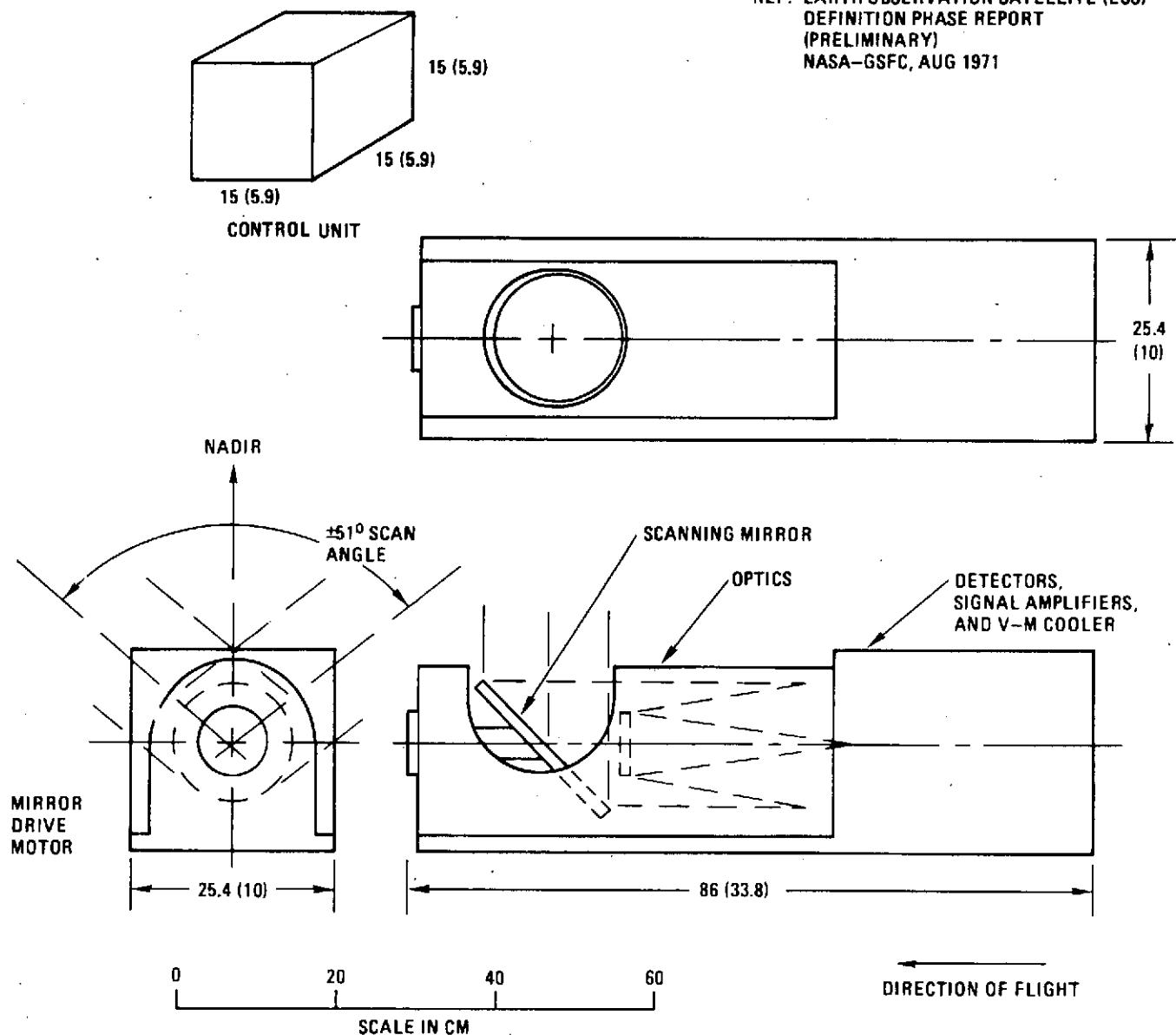
2) "CARBON MONOXIDE POLLUTION EXPERIMENT"
AAFE PRINCIPAL INVESTIGATION REVIEW, OCT 5-6, 1971,
PP 215-237

A-22

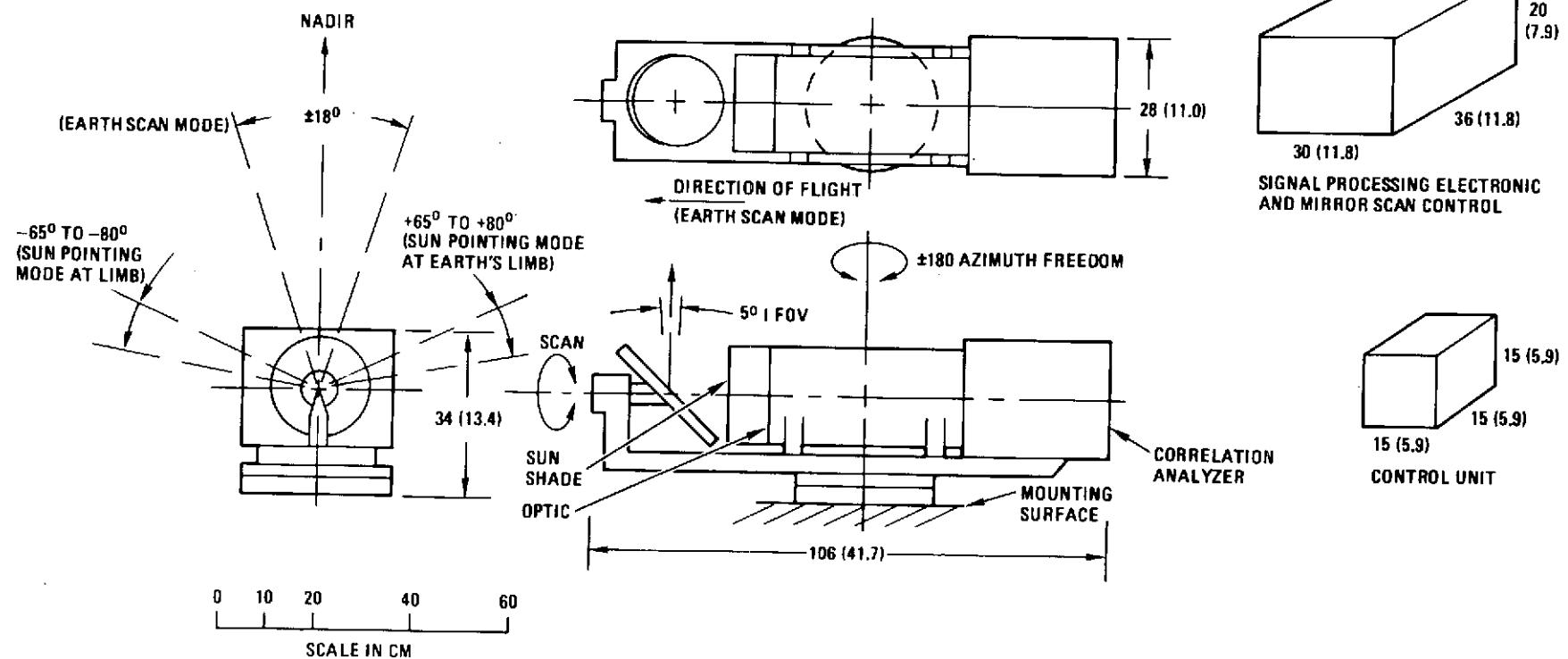


Sensors Nos. 22 and 23. High Speed Interferometer (No. 21) and
Carbon Monoxide Pollution Experiment (No. 21)

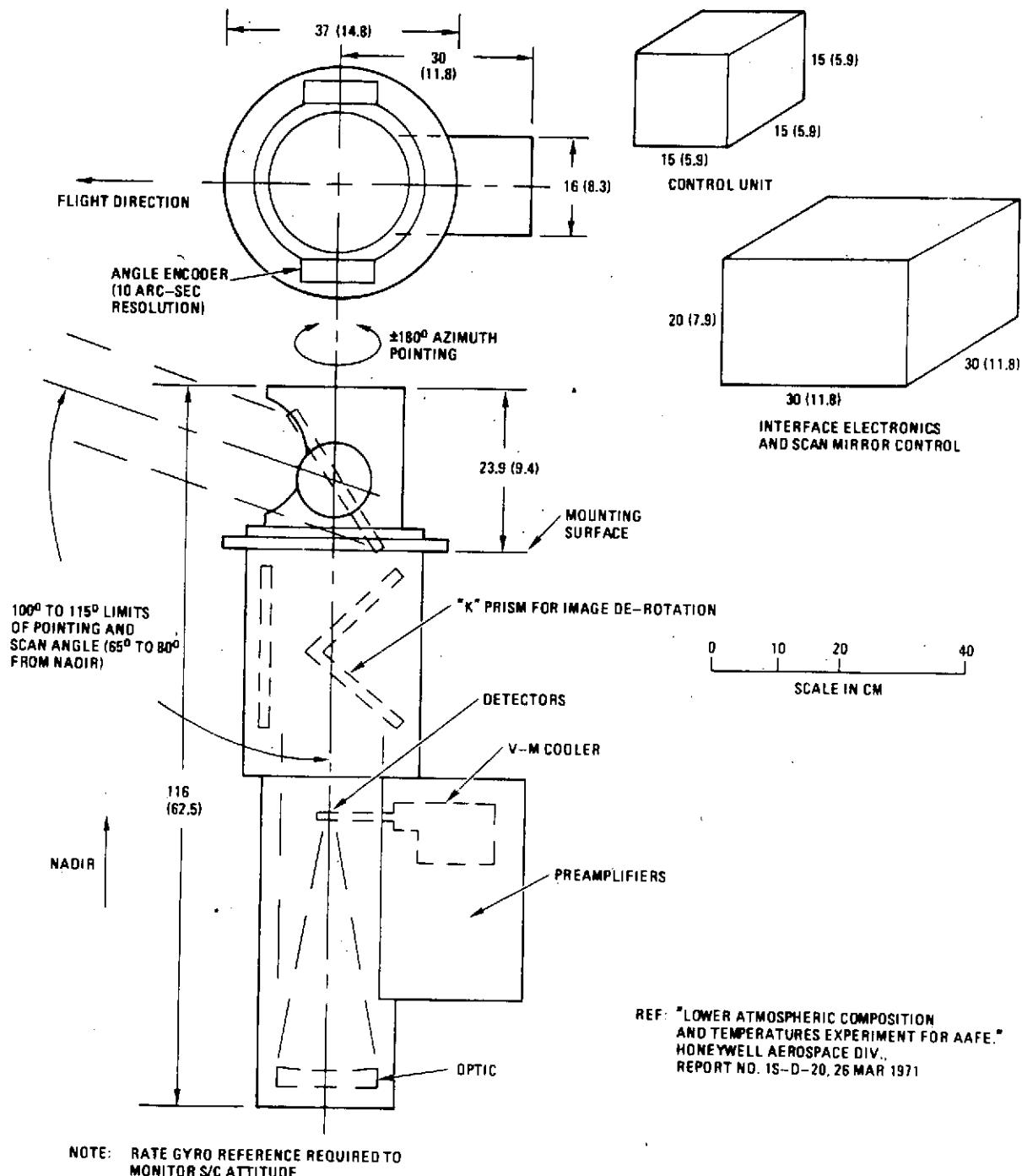
REF: EARTH OBSERVATION SATELLITE (ECS)
DEFINITION PHASE REPORT
(PRELIMINARY)
NASA-GSFC, AUG 1971



Sensor No. 24. Cloud Physics Radiometer

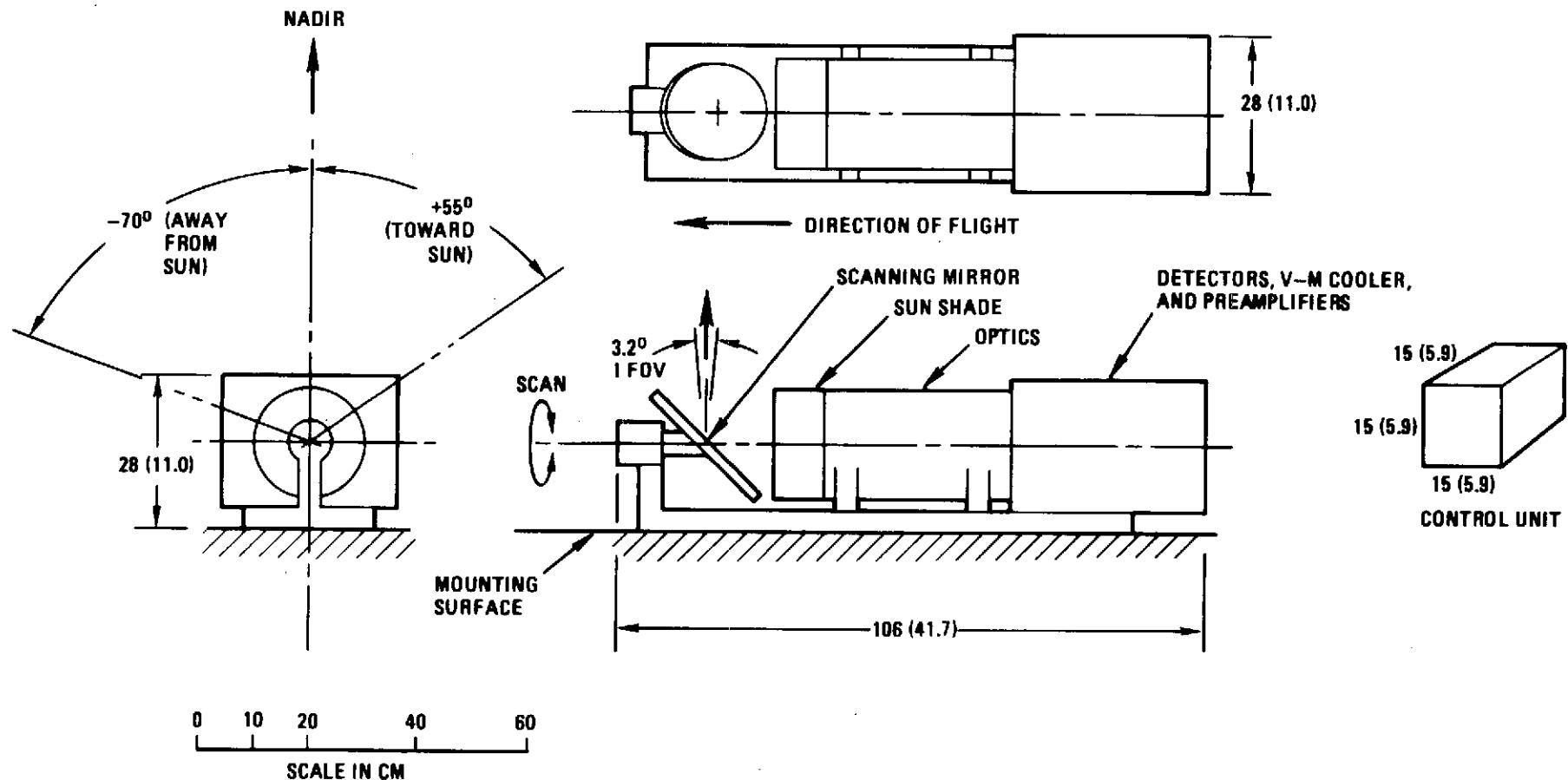


Sensor No. 25. Remote Gas Filter Correlation Analyzer

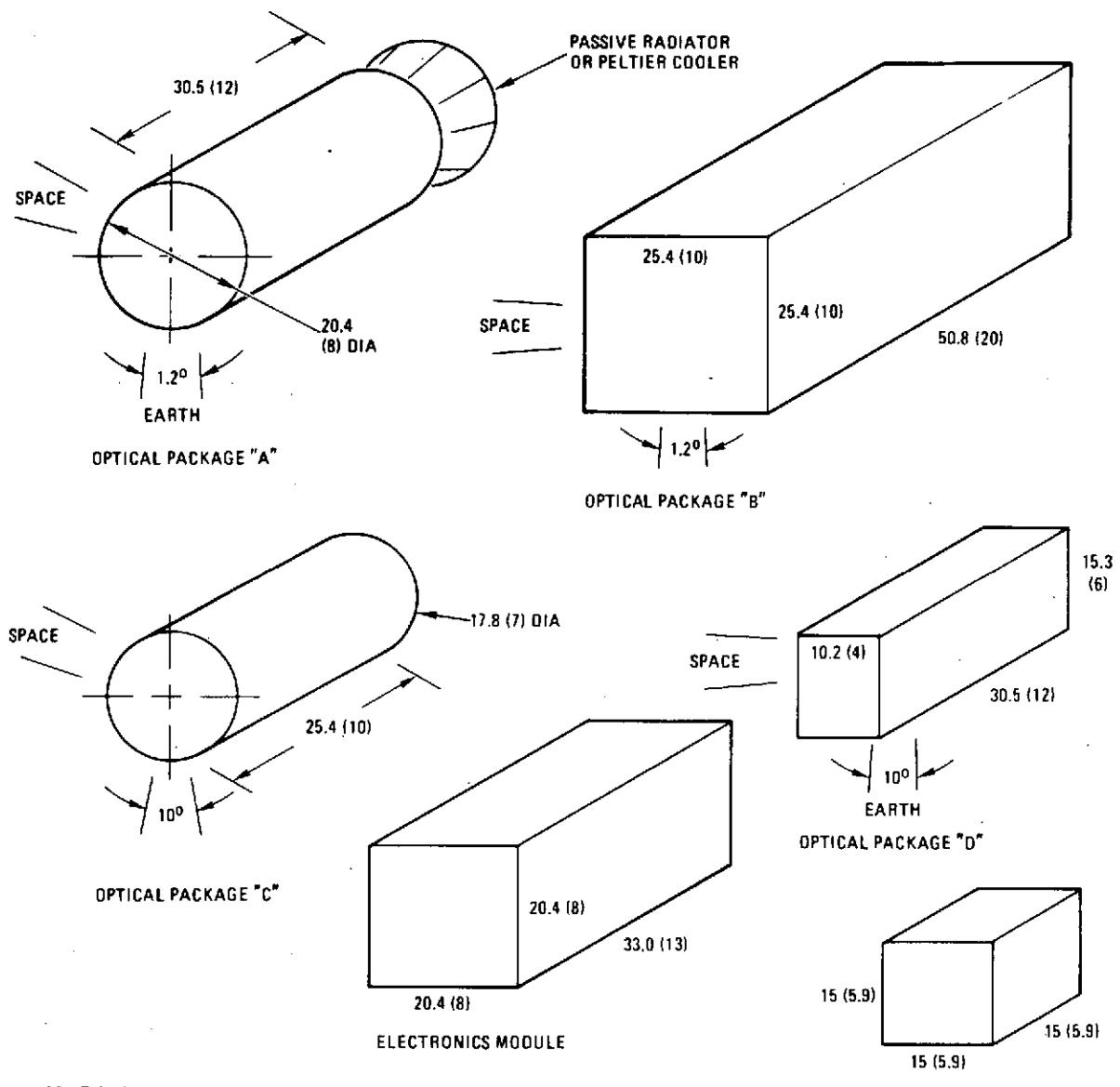


Sensor No. 26. Advanced Limb Radiance Inversion Radiometer

A-26



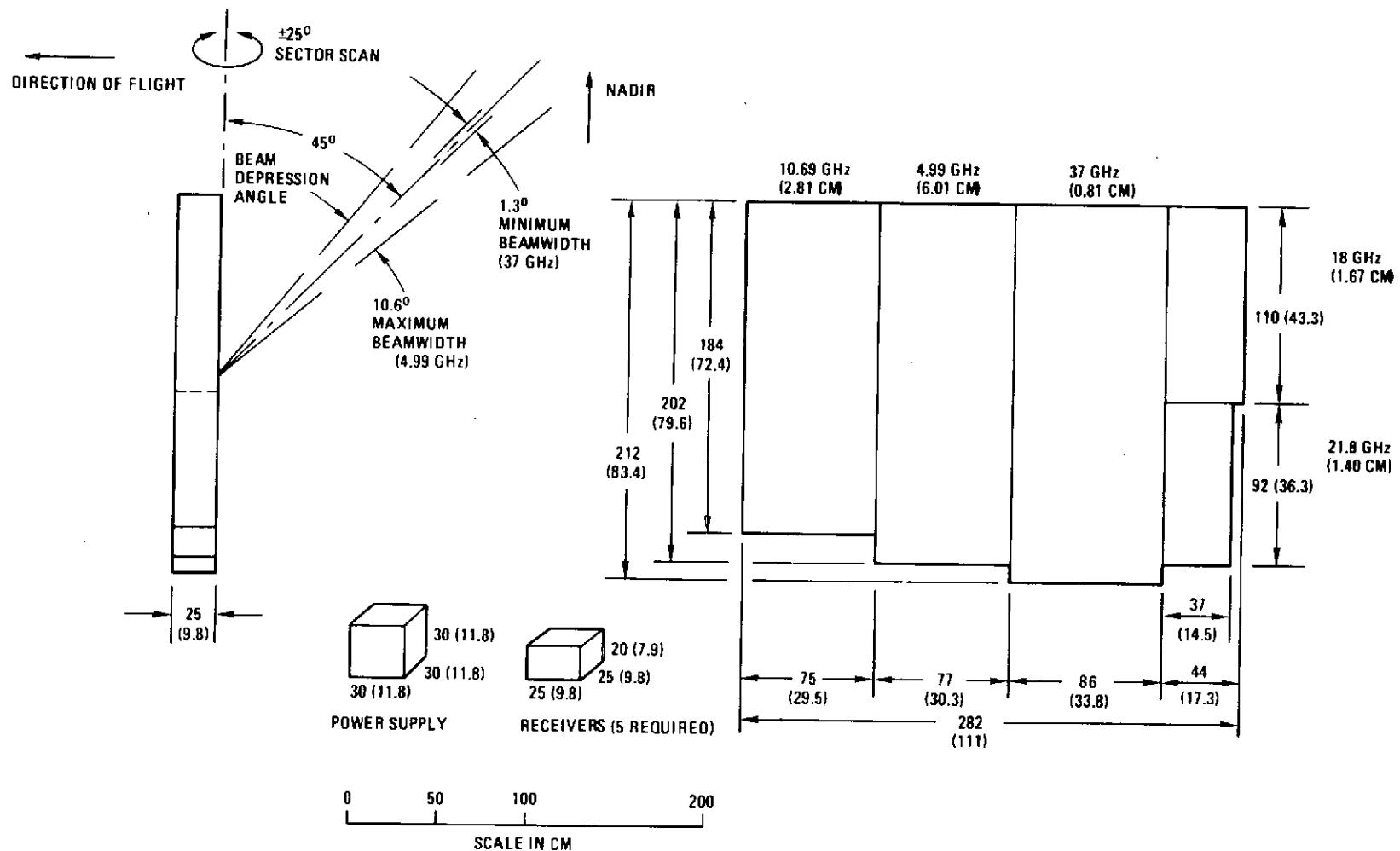
Sensor No. 27. Tiros-N Advanced Very High Resolution Radiometer



REF: TIROS-N PHASE A REPORT, VOL. 2,
NASA-GSFC, MAR 1971, PP A-11, 12

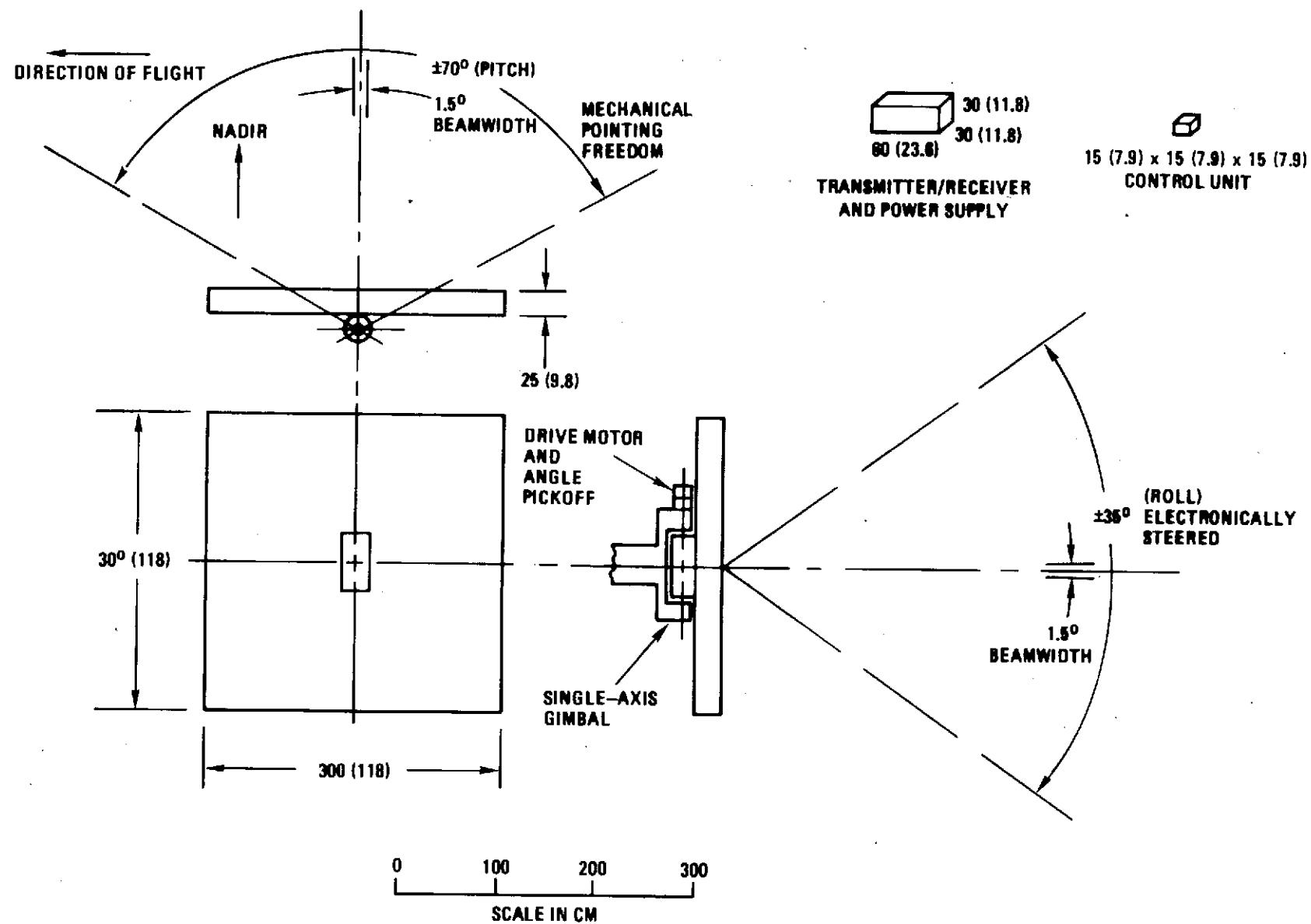
Sensor No. 28. Tiros-N Operational Vertical Sounder

A-28

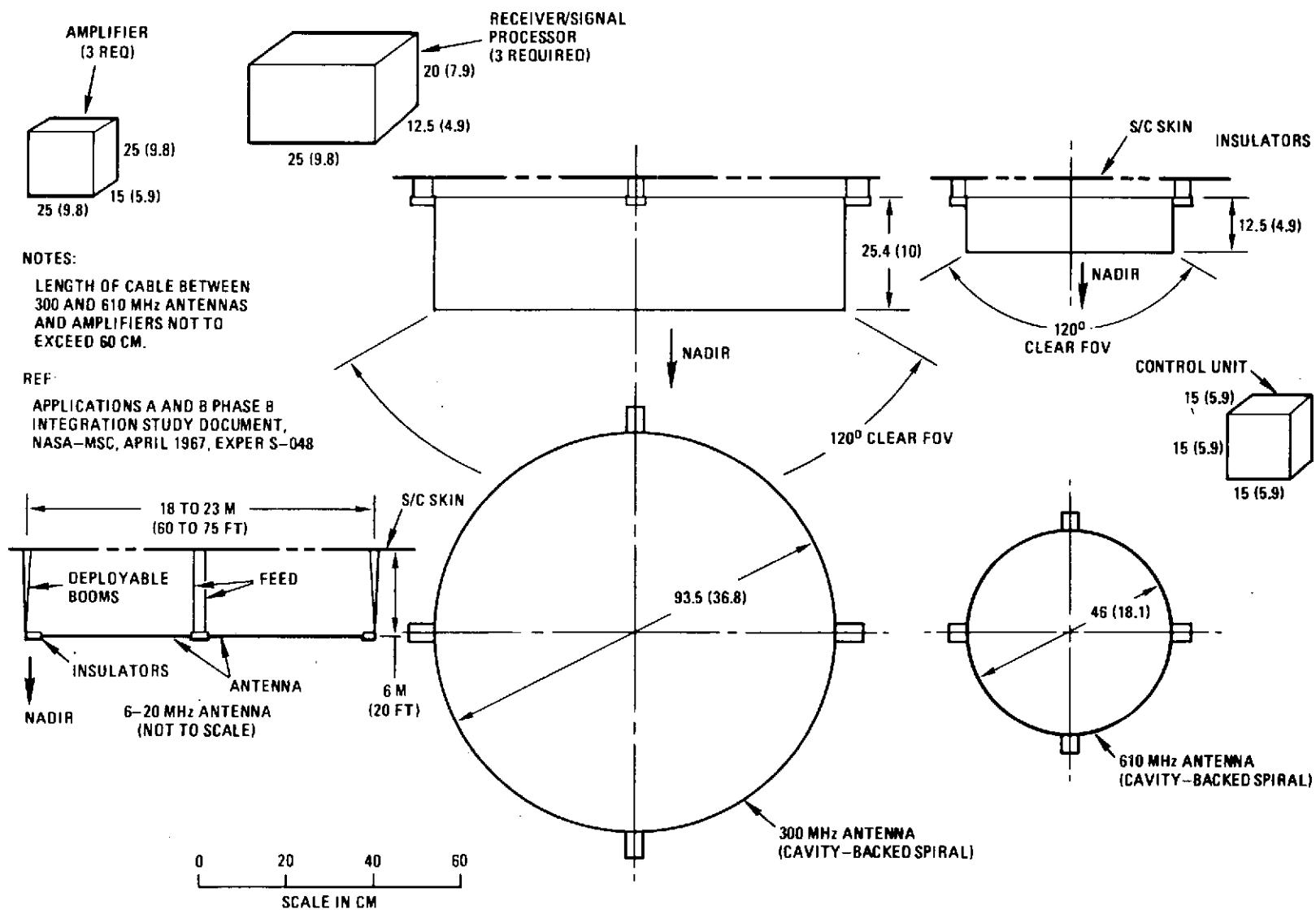


REF: EARTH OBSERVATORY SATELLITE (EOS)
DEFINITION PHASE REPORT (PRELIMINARY)
NASA-GSFC AUG 1971

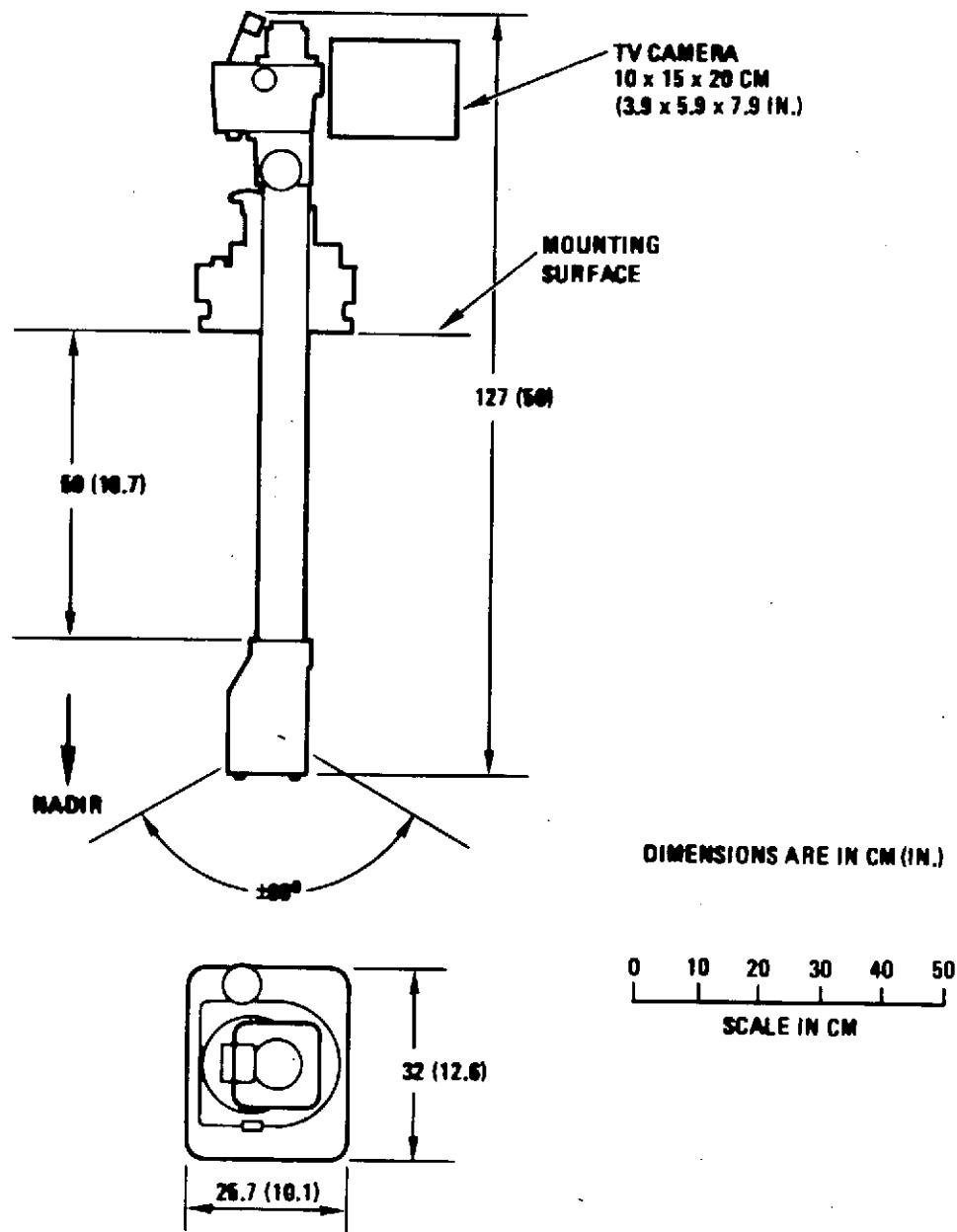
Sensor No. 29. Passive Multichannel Microwave Radiometer



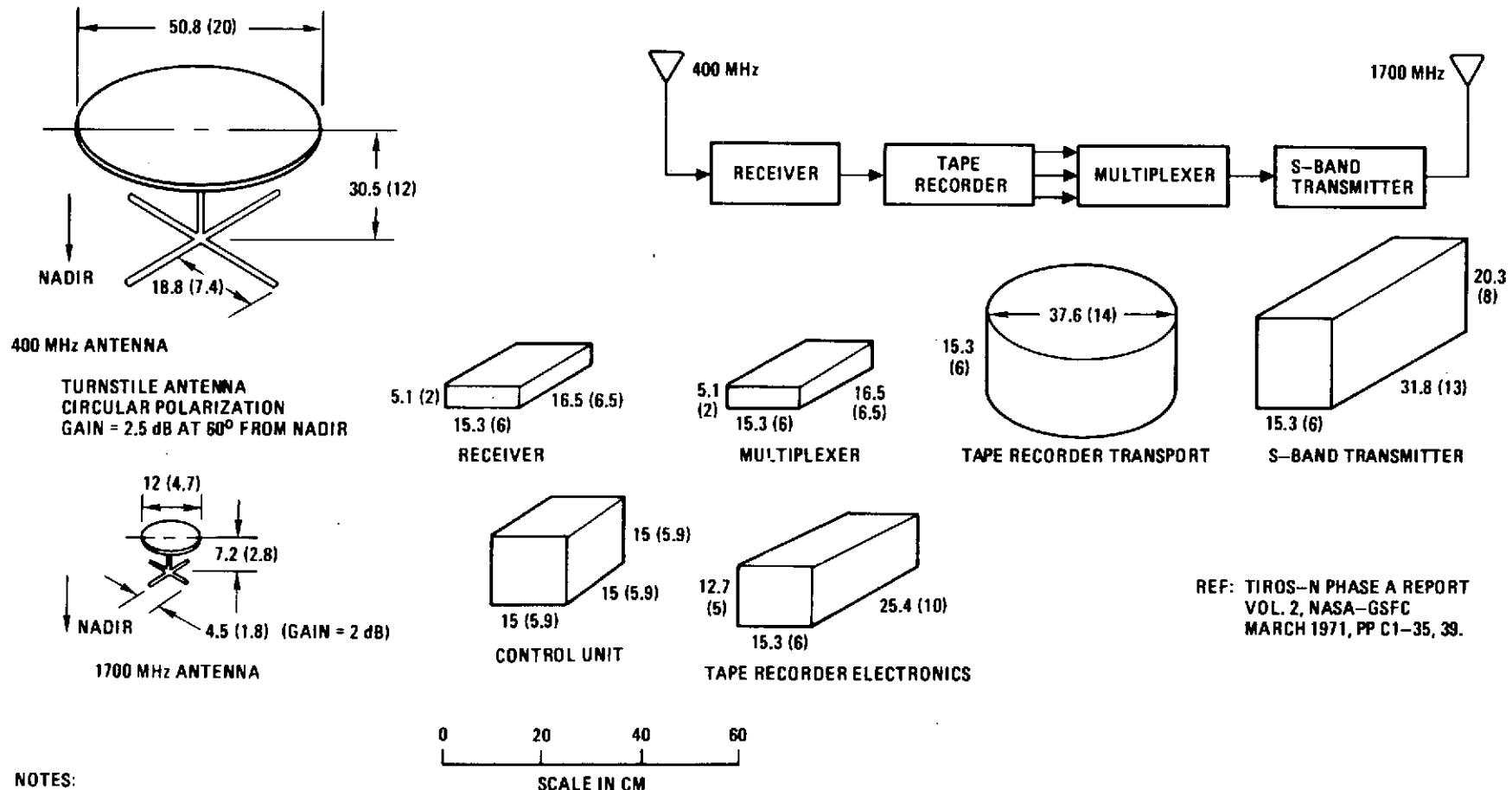
Sensor No. 30. Microwave Radiometer/Scatterometer



Sensor No. 31. Sferics Receiver



Sensor No. 32. Wide Angle Viewer/Hydrogen Alpha Line Viewer



Sensor No. 33. Data Collection System

APPENDIX B

SENSOR CONTROL AND DISPLAY REQUIREMENTS-- LOW-COST POLLUTION MISSION

For the sixteen sensors used in the Low-Cost Pollution Mission, the preliminary interface data contained in this Appendix has been developed in order to define the control and display requirements for this mission.

In addition, interface data is presented for the Precision Attitude Determination System (PADS), which is recommended for use in establishing a coordinate reference frame (local vertical-roll, pitch, and yaw) and for use in pointing of the sensors.

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 1	TITLE: TRACKING TELESCOPE			
CONFIGURATION:				
Refractive Telescope 25.4 cm. (10 in.) dia., f/7.5, with 4/1 magnification change and 2/1 200M capability. Scene Rotation Compensation. Two-Axis. Four Element Filter Wheel. Identification Camera Using 35 mm. Film.				
CONTROL FUNCTIONS: (Each Camera)				
1. Structure Assembly Door a. Open Command b. Close Command 2. Gyro Command Signal a. On b. Off 3. Heater Power Inhibit Signal a. On b. Off 4. Lens Zoom Drive a. Higher Magnification b. Lower Magnification 5. Image Rotation a. CW b. CCW		6. Camera Trigger 7. Heater Control a. On b. Off		
STATUS DATA: (Each Camera)				
1. Scanner Gimbal Position Readout a. Roll 1. CW Signal (20 bits) 2. CCW Signal (20 bits) b. Pitch 1. CW Signal (18 bits) 2. CCW Signal (18 bits) 2. Scanner Gimbal Sector Signal a. Roll 1. 0 Deg. 2. +56.25 Deg. 3. Scanner Gimbal Limit Signal a. Roll b. Pitch		4. Structure Asmb. Door Limit Sw. a. Closed 1. In Limit, 2. Out of Limit 5. Gyro Temp. (0 - 5 V. DC) a. Pitch Gyro, b. Roll Gyro 6. Gyro Output Signals (< +20V DC) a. Pitch Gyro, b. Roll Gyro 7. Gyro Speed a. Pitch Gyro, b. Roll Gyro 8. Zoom Limit a. Max. Limit, b. Min. Limit 9. Optical Asmb. Temp. (6 Reqd) (0 - 5 V. DC)		
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display				
CRT DISPLAY:				
Ref: Flight Hardware End Item Specification, Tracking Telescope Subsystem, Manned Earth Viewing System, Itek Report No. 70-8327-2, 22 Sept 1970, Itek Corp., Optical Systems Division, Lexington, Mass. 02173 pp 14-24				

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 2	TITLE: POINTABLE IDENTIFICATION CAMERA	
CONFIGURATION:	Two Cameras, 70 mm Film B&W and Color Film, Two-Axis Gimbals	
CONTROL FUNCTIONS:		
<u>For Each Camera</u>		<u>For Combinations of Two Cameras</u>
1. Off/Single-Frame/Continuous 2. Shutter Speed 3. Lens Aperture 4. Objective Aperture Open/Closed		1. Overlap Ratio 2. Shutter Release 3. Gimbal Angles (2) a. Manual b. Automatic
STATUS DATA:		
<u>For Each Camera</u>		<u>For Combinations of Two Cameras</u>
1. Frame Counter (F), (P) 2. Shutter Speed (F) 3. Lens Aperture (F) 4. Overlap Ratio (F) 5. Film Type (F) 6. Filter Type (F) 7. Camera Temperature (P) 8. Camera Pressure (P) 9. Film Remaining (P) 10. Time (F) 11. Orbit No. (F)		1. Two Gimbal Angles (F), (P)
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display		
CRT DISPLAY:	N/A	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 5	TITLE: MULTISPECTRAL CAMERA SYSTEM			
CONFIGURATION: Six Cameras, 24 x 24 cm film, B&W and Color Film, One Single-Axis Gimbal. Simultaneous operation of either all six or only two cameras required.				
CONTROL FUNCTIONS:				
<u>For Each Camera</u>		<u>For Combinations of 2 or 6 Cameras</u>		
1. Off/Single-Frame/Continuous 2. Shutter Speed 3. Lens Aperture 4. Objective Aperture Open/Closed		1. Overlap Ratio 2. Shutter Release 3. Gimbal Angle (1) a. Manual b. Automatic		
STATUS DATA:				
<u>For Each Camera</u>		<u>For Combinations of 2 or 6 Cameras</u>		
1. Frame Counter (F), (P) 2. Shutter Speed (F) 3. Lens Aperture (F) 4. Overlap Ratio (F) 5. Film Type (F) 6. Filter Type (F) 7. Camera Temperature (P) 8. Camera Pressure (P) 9. Film Remaining (P) 10. Time (F) 11. Orbit No. (F)		1. Gimbal Angle (F), (P)		
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display				
CRT DISPLAY: N/A				

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 6	TITLE: HIGH RESOLUTION MULTISPECTRAL CAMERA SYS.	
CONFIGURATION:	Six Cameras, 70 mm film, B&W and Color Film. Two Axis Gimbals. Simultaneous Operation of Six Cameras Required.	
CONTROL FUNCTIONS:		
<u>For Each Camera</u>		<u>For Combination of 6 Cameras</u>
1. Off/Single-Frame/Continuous 2. Shutter Speed 3. Lens Aperture 4. Objective Aperture Open/Closed		1. Overlap Ratio 2. Shutter Release 3. Gimbal Angles (2) a. Manual b. Automatic
STATUS DATA:		
<u>For Each Camera</u>		<u>For Combination of 6 Cameras</u>
1. Frame Counter (F), (P) 2. Shutter Speed (F) 3. Lens Aperture (F) 4. Overlap Ratio (F) 5. Film Type (F) 6. Filter Type (F) 7. Camera Temperature (P) 8. Camera Pressure (P) 9. Film Remaining (P) 10. Time (F) 11. Orbit No. (F)		1. Two Gimbal Angles (F), (P)
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display		
CRT DISPLAY: N/A		

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 7	TITLE: MULTIRESOLUTION FRAMING CAMERA SYSTEM			
CONFIGURATION: Three Cameras, 24 x 24 cm. film, False Color Film, 46, 92, 184 cm. f. l. lenses, Single-Axis Gimbal. Simultaneous operation of three cameras required.				
CONTROL FUNCTIONS:				
For Each Camera		For Combinations of 3 Cameras		
1. Off/Single Frame/Continuous		1. Interval Between Frames (Sec.)		
2. Shutter Speed		2. Shutter Release		
3. Lens Aperture		3. Gimbal Angle (1)		
4. Objective Aperture Open/Closed		a. Manual b. Automatic		
STATUS DATA:				
For Each Camera		For Combination of 3 Cameras		
1. Frame Counter (F), (P)		1. Gimbal Angle (F), (P)		
2. Shutter Speed (F)				
3. Lens Aperture (F)				
4. Interval Between Frames (Sec.) (F)				
5. Film Type (F)				
6. Filter Type (F)				
7. Camera Temperature (P)				
8. Camera Pressure (P)				
9. Film Remaining (P)				
10. Time (F)				
11. Orbit No. (F)				
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display				
CRT DISPLAY: N/A				

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 8	TITLE: HIGH RESOLUTION WIDEBAND MULTISPECTRAL SCANNER
CONFIGURATION:	Reflective Optic, Image-Plane Scanning, 20 Spectral Filters and Detectors, Vuilleumier Cooler, One Single-Axis Gimbal.
CONTROL FUNCTIONS: (Each Camera)	
1. Power On/Off	6. Objective Aperture Cover a. Open b. Closed
2. Mode a. Standby b. Check c. Ready	7. Gimbal Angle a. Manual b. Automatic
3. Calibration Source No. 1 Power On/Off a. Low b. High	
4. Calibration Source No. 2 Power On/Off a. Low b. High	
5. Calibration Source No. 3 Power On/Off a. Low b. High	
STATUS DATA: (Each Camera)	
1. Detector Temperature (2), (P), (M)	
2. Optics Temperature (10), (P), (M)	
3. Blackbody Temperature (6), (P), (M)	
4. Calibration Lamp Current (2), (P), (M)	
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display	
CRT DISPLAY:	
1. Monochrome display of data from any one of 20 spectral bands in real time.	
2. Color display of data from several spectral bands in real time.	
Data Rate/Spectral Band = 20 Mb/sec. @ 33% duty cycle Ref: Contract NAS9-11196, Exhibit 3, End Item Spec. for Multispectral Scanner, 8-27-71, pp 34, 36	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 13	TITLE: VISIBLE IMAGING SPECTROMETER
CONFIGURATION:	Three Multiband Ocean Color Sensors Oriented in a Pushbroom Configuration and Strapped Down to S/C Structure
CONTROL FUNCTIONS:	
<u>For Each of 3 Sensors</u>	
<ol style="list-style-type: none"> 1. Power On/Off 2. Objective Aperture Open/Closed 3. Mode <ul style="list-style-type: none"> a. Standby b. Operate/High Resolution c. Operate/Low Resolution 4. Calibration Source On/Off 5. Video Output Gain 	
STATUS DATA:	
<u>For Each of 3 Sensors</u>	
<ol style="list-style-type: none"> 1. IDT Photocathode Temperature (M), (P) 2. HVPS Voltage (M), (P) 3. Calibration Source Current (M), (P) 4. LVPS Voltages (5), (M), (P) 5. Video Output Gain (M), (P) 	
<p>(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display</p> <p>CRT DISPLAY:</p> <ol style="list-style-type: none"> 1. Monochrome display of data from any one of 20 spectral bands, or differential signal between any two of 20 spectral bands. 2. Color display of data from several spectral bands, or differential signals from selected spectral bands. 	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 14	TITLE: IR MULTISPECTRAL MECHANICAL SCANNER
CONFIGURATION:	5-Band Multispectral Scanner for Thermal Mapping of Sea Surface. Conical Scanning about the Nadir. Strapped-down to S/C.
CONTROL FUNCTIONS: (Each Camera)	<ol style="list-style-type: none">1. Power On/Off2. Objective Aperture Cover<ol style="list-style-type: none">a. Openb. Closed3. Calibration Source No. 1 Power On/Off<ol style="list-style-type: none">a. Lowb. High4. Calibration Source No. 2 Power On/Off<ol style="list-style-type: none">a. Lowb. High5. Calibration Source No. 3 Power On/Off<ol style="list-style-type: none">a. Lowb. High
STATUS DATA: (Each Camera)	<ol style="list-style-type: none">1. Detector Temperature (5), (P), (M)2. Optics Temperature (5), (P), (M)3. Blackbody Temperature (6), (P), (M)4. Calibration Lamp Current (2), (P), (M)
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display	
CRT DISPLAY:	<ol style="list-style-type: none">1. Monochrome display of data from any one of five spectral bands in real time.<ol style="list-style-type: none">a. Band 1 - daytime cloudsb. Band 2 - night time cloudsc. Band 3 - water vapord. Band 4 - water vapore. Band 5 - sea surface temp.

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 20	TITLE: VISIBLE RADIATION POLARIMETER
CONFIGURATION:	Optical System, Spectral Filters, Polarizing Filters, Silicon Detectors. Sensor Mounted in Two-Axis Gimbal System. One, Three, or Four Spectral Bands Used Simultaneously Depending Upon Experiment.
CONTROL FUNCTIONS: (Each Camera)	
1. Power On/Off	6. Mode
2. Objective Aperture Cover	a. Calibrate
a. Open	b. Operate
b. Closed	7. Calibration Source Power On/Off
3. Gimbal Angles (2)	a. Low
a. Manual	b. High
b. Automatic	
4. Objective Aperture Open/Closed	
5. Spectral Filter Selection	
a. One of seven filters	
b. Two of seven filters	
c. Four of seven filters	
STATUS DATA: (Each Camera)	
1. Detector Temperature (1), (P), (M)	
2. Optics Temperature (3), (P), (M)	
3. Channel Selector Wheel Position (One Tic Mark/Revolution)	
4. Gimbal Angles (2), (P), (M)	
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display	
CRT DISPLAY:	
1. A Scan Display in Real Time	
a. Intensity, Channel A	
b. Intensity, Channel B	
c. Intensity, Channel D	
d. Intensity, Channel A - Channel B	
e. Intensity, Channel A - Channel D	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 21	TITLE: AIR POLLUTION CORRELATION SPECTROMETER
CONFIGURATION:	Scanning Mirror, Optical System, Dual Correlation Spectrometer
CONTROL FUNCTIONS: (Each Camera)	<ol style="list-style-type: none">1. Power On/Off<ol style="list-style-type: none">a. Spectrometer No. 1b. Electronics No. 1c. Spectrometer No. 2d. Electronics No. 22. Calibration Source No. 1<ol style="list-style-type: none">a. Lowb. High3. Calibration Source No. 2<ol style="list-style-type: none">a. Lowb. High4. Objective Aperture Open/Closed
STATUS DATA: (Each Camera)	<ol style="list-style-type: none">1. Electronics Supply Voltages (10), (P), (M)2. Detector Temperatures (2), (P), (M)3. Calibration Source Current (2), (P), (M)4. Optics Temperature (8), (P), (M)
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display	<p>CRT DISPLAY:</p> <ol style="list-style-type: none">1. A-Scan Display of either raw or processed signal data (2 channels). <p>Note: Preliminary data, to be superceded by more definitive information when available.</p>

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 22	TITLE: HIGH SPEED INTERFEROMETER (HSI)
CONFIGURATION:	Optics, Michelson Interferometer, Chopper, Pyroelectric Detectors (uncooled), Reference Blackbody Source, HeNe Laser with PMT Detector.
CONTROL FUNCTIONS: (Each Camera)	<ol style="list-style-type: none">1. Power On/Off<ol style="list-style-type: none">a. Electronicsb. Interferometerc. Laserd. PMT High Voltage2. Calibration Source No. 1 On/Off<ol style="list-style-type: none">a. Lowb. High3. Calibration Source No. 2 On/Off<ol style="list-style-type: none">a. Lowb. High4. Objective Aperture Open/Closed
STATUS DATA: (Each Camera)	<ol style="list-style-type: none">1. Electronics Supply Voltages (8), (P), (M)2. Detector Temperature (P), (M)3. Calibration Source Temperature (4), (P), (M)
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display	<p>CRT DISPLAY:</p> <ol style="list-style-type: none">1. A-Scan Display of either raw or processed signal data (1 channel only). <p>Note: Tentative data, based upon completion of sensor design for flight.</p>

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 23	TITLE: CARBON MONOXIDE POLLUTION EXPERIMENT (COPE)
CONFIGURATION:	Michelson Interferometer, Optical System, Infrared Detector, Peltier Cooler, Signal Processing Electronics
CONTROL FUNCTIONS:	(Each Camera)
1.	Power On/Off a. Electronics b. Interferometer c. Peltier Cooler
2.	Calibration Source On/Off a. Low b. High
3.	Objective Aperture Open/Closed
STATUS DATA:	(Each Camera)
1.	Electronics Supply Voltages (4), (P), (M)
2.	Detector Temperature (P), (M)
3.	Calibration Source Temperature (P), (M)
4.	Optics Temperature (4), (P), (M)
<p>(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display</p>	
CRT DISPLAY:	
1.	A-Scan Display of either raw or processed signal data (1 channel only).
<p>Note: Preliminary data, to be superceded by more definitive information when available.</p>	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 25	TITLE: REMOTE GAS FILTER CORRELATION ANALYZER
CONFIGURATION:	Objective Lens, Selective Gas Filters, Infrared Detectors (8), Closed Cycle Cooler, Cross-Track Scan with Rotating Mirror.
CONTROL FUNCTIONS: (Each Camera)	<ol style="list-style-type: none">1. Power On/Off<ol style="list-style-type: none">a. Electronicsb. Scannerc. V-M Cooler2. Calibration Source No. 1 Power On/Off<ol style="list-style-type: none">a. Lowb. High3. Calibration Source No. 2 Power On/Off<ol style="list-style-type: none">a. Lowb. High4. Calibration Source No. 3 Power On/Off<ol style="list-style-type: none">a. Lowb. High5. Objective Aperture Open/Closed
STATUS DATA: (Each Camera)	<ol style="list-style-type: none">1. Electronics Supply Voltages (4), (P), (M)2. Detector Temperature (1), (P), (M)3. Calibration Source Temperature (3), (P), (M)4. Optics Temperature (4), (P), (M)5. Scan Mirror Position (P), (M)
(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display	CRT DISPLAY: <ol style="list-style-type: none">1. A-Scan Display of signals from any one of eight signal channels.
Note: Tentative data, based upon completion of sensor design for flight.	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 26	TITLE: ADVANCED LIMB RADIANCE INVERSION RADIOMETER (ALRIR)
CONFIGURATION: Radiometer, Interface Electronics, Scanning Mirror, HgCdTe Detectors, V-M Cooler, Blackbody Calibration Source	
CONTROL FUNCTIONS: (Each Camera)	
<ol style="list-style-type: none">1. Power On/Off<ol style="list-style-type: none">a. Electronicsb. Scannerc. V-M Cooler2. Calibration Source No. 1 On/Off<ol style="list-style-type: none">a. Lowb. High3. Calibration Source No. 2 On/Off<ol style="list-style-type: none">a. Highb. Low4. Objective Aperture Open/Closed	
STATUS DATA: (Each Camera)	
<ol style="list-style-type: none">1. Electronics Supply Voltages (4), (P), (M)2. Detector Temperature (1), (P), (M)3. Calibration Source Temperature (2), (P), (M)4. Optics Temperature (4), (P), (M)5. Scan Mirror Position (P), (M)	
<p>(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display</p> CRT DISPLAY:	
<ol style="list-style-type: none">1. A-Scan Display of signals from any of ten signal channels. <p>Note: Tentative Data, based upon completion of sensor design for flight.</p>	

CONTROL AND DISPLAY REQUIREMENTS

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 33	TITLE: DATA COLLECTION SYSTEM
CONFIGURATION:	Antenna, Receiver, Multiplexer, Tape Recorder, S-Band Transmitter
CONTROL FUNCTIONS: (Each Camera)	
<ol style="list-style-type: none">1. Power<ol style="list-style-type: none">a. Onb. Off2. Tape Recorder<ol style="list-style-type: none">a. Recordb. Playback3. Transmitter<ol style="list-style-type: none">a. Onb. Off	
STATUS DATA: (Each Camera)	
<ol style="list-style-type: none">1. Tape Recorder Drive (P)<ol style="list-style-type: none">a. Stoppedb. Running2. Power On/Off<ol style="list-style-type: none">a. Receiverb. Tape Recorder Electronicsc. Multiplexerd. Transmitter	
<p>(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display</p>	
CRT DISPLAY: N/A	

CONTROL AND DISPLAY REQUIREMENTS

SENSOR NO. 34	TITLE: PRECISION ALTITUDE DETERMINATION SYSTEM
<p>CONFIGURATION: Star Tracker and Gyro Assemblies Mounted on Reference Block Assembly. Alignment Sensor Monitors Attitude of RBA to S/C. Sensor Electronics Assembly Controls Star Tracker. Digital Operational Controller Performs All System Computations.</p>	
<p>CONTROL FUNCTIONS: (Each Camera)</p>	
<ol style="list-style-type: none">1. Star Tracker Assembly On/Off2. Gyro Reference Assembly On/Off<ol style="list-style-type: none">a. Gyros Caged/Uncaged3. Alignment Sensor On/Off4. Sensor Electronics Assembly On/Off5. Digital Operational Controller On/Off	
<p>STATUS DATA:</p> <ol style="list-style-type: none">1. S/C. Ephemeris Data (P), (M)2. a. Time b. Latitude c. Longitude d. Inclination e. Altitude3. Star Tracker Data (P), (M)<ol style="list-style-type: none">a. Star Catalog No.b. Mode (Search/Track)4. Gyro Ref. Assem. On/Off (P), (M)5. Alignment Sensor On/Off (P), (M)6. Sensor Electronics Assembly On/Off (P), (M)7. Dig. Oper. Cont. On/Off (P), (M)8. Gyros-Caged/Uncaged (P), (M)9. Payload Sensor Data (P), (M) (for each sensor on payload)<ol style="list-style-type: none">a. Gimbal Angle No. 1b. Gimbal Angle No. 2c. Gimbal Angle No. 3d. Target Latitudee. Target Longitude	
<p>(F) = Film Block; (M) = Magnetic Tape; (P) = Panel Display</p>	
<p>CRT DISPLAY: No CRT display required.</p>	

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